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FA-TN-75003

DEVELOPMENT OF A FLEXIBLE INTERNAL ELEMENT (FIE) FOR ALUMINUM CASED AMMUNITION

January 1975

FRANKFORD ARSENAL • U.S. ARMY ARMAMENT COMMAND • PHILADELPHIA, PENNSYLVANIA 19137

Munitions Development and Engineering Directorate

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aluminum	Flexible Internal Element (FIE)	Specific gravity
Burn-through	Polysulfide	5.56 mm aluminum case
Erosion	Pre-formed FIE	Propellant
Flash	Elongation	Gap

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

It had been successfully demonstrated by Frankford Arsenal that a liquid Flexible Internal Element (FIE) injected into a case will prevent the catastrophic burn-through associated with aluminum case structural failure. The primary purpose of this study was to develop an FIE composition that could be preformed and perform at least equally to liquid FIE. This work was undertaken to establish a preformed FIE and an

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18. SUPPLEMENTARY NOTE - Cont'd

Philadelphia, Pennsylvania 19137. Inclusive dates of this investigation were 28 June 1973 to 30 June 1974. The representatives from Frankford Arsenal were Mr. S. J. Marziano, Technical Supervisor, and H. Legman, Contracting Officer. The representatives from Thiokol Corporation were Dr. C. W. Vriesen, Principal Investigator, E. C. Oosterom and L. J. Earner, Program Managers, and J. M. Stong and A. S. Butler, Contract Specialists.

19. KEY WORDS - Cont'd

FIE configuration
Tensile strength
Chamber pressure
Polyurethane
Insert
Dihydroxyglyoxime (DHG)

20. ABSTRACT - Cont'd

experimental fabrication process prior to manufacturing a quantity of 6.00 mm aluminum cases for the SAW program. For convenience, 5.56 mm cases were used before 6.00 mm cases were available. The Elkton Division of the Thiokol Corporation, Elkton, Maryland, was commissioned to conduct the study and prepare samples which were test fired and evaluated at Frankford Arsenal. A series of Flexible Internal Element (FIE) sealing cups were fabricated from several polysulfide formulations and test fired. Of the formulations tested, three types, identified as P10, P18, and P28, were effective in preventing erosion and flash, otherwise known as burn-through, in aluminum cased ammunition. Target properties of the sealing cup compositions were: specific gravity greater than 1.04, a cost of less than \$.01/CM^3, tensile strength greater than 300 psi, and elongation greater than 300 percent. The effectiveness demonstrated by samples P10, P18, and particularly P28, has proven the feasibility of utilizing preformed polysulfide cups as a means of preventing burn-through.

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INTRODUCTION

The primary objective of this study was to develop a preformed Flexible Internal Element (FIE) sealing cup that could be used in aluminum alloy cased ammunition (Figure 1). This work was undertaken to establish a preformed FIE and an experimental fabrication process prior to manufacturing a quantity of 6.00 mm aluminum cases for the Squad Automatic Weapon (SAW) program. For convenience, 5.56 mm cases were used before 6.00 mm cases were available. It had been shown[1] by Frankford Arsenal that a liquid FIE material (RTV-734) injected into a case will prevent the catastrophic burn-through associated with aluminum case structural failure. The FIE, during firing, is forced into the gas flow path preventing the hot propellant gas from escaping around the case head.

It has been shown that a split in the wall of an aluminum case through which propellant gas can flow during the internal ballistic cycle is a precursor to a burn-through phenomenon.[2] Severe erosion of the case occurs during the burn-through and is accompanied by a large flash next to the breech of the weapon. It has been established that the gases reach a peak flame temperature of 4400° F in less than one millisecond and that components are nitrogen, carbon dioxide, carbon monoxide, oxygen and hydrogen.

A previous program,[3] conducted under Frankford Arsenal contract (DAAA25-73-M-0019) by the Elkton Division of Thiokol Corporation, Elkton, Maryland, involved the screening of six coatings which might prevent the burn-through phenomenon. The coatings were:

1. Graphite containing epoxy-polysulfide deposited internally from a solvent
2. Red Grip Filler in RTV-734 binder (internal)
3. RTV-734 in methylene chloride applied externally
4. Six external layer applications of DuPont RK-692 polyimide varnish

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[1] Reed E. Donnard and Thomas J. Hennessy, " Aluminum Cartridge Case Feasibility Study Using the M16A1 Rifle with the 5.56 mm Ball Ammunition as the Test Vehicle," Frankford Arsenal Report No. R-2065, November 1972.

[2] W. H. Squire and R. E. Donnard, "An Analysis of 5.56 mm Aluminum Cartridge Case Burn-Through Phenomenon," Frankford Arsenal, AD 750379, 1972.

[3] Samuel J. Marziano and Dr. Calvin Vriesen, " Prevention of 5.56 mm Aluminum Cartridge Case Burn-Through," Frankford Arsenal Report No. FA-TN-75002, January 1975.

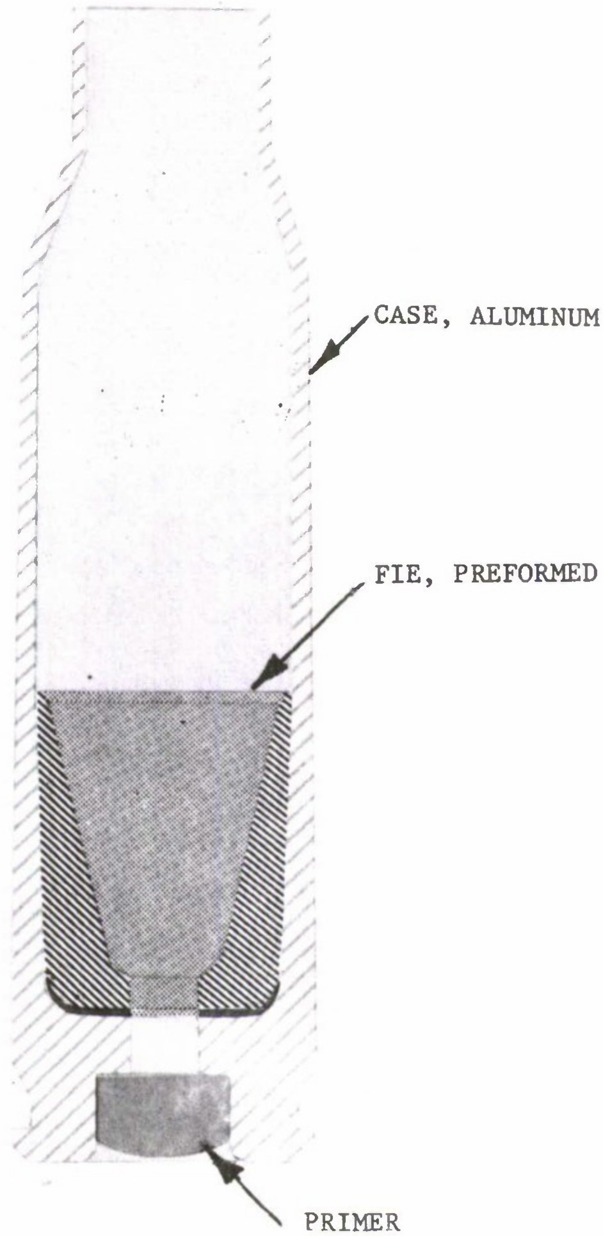

Figure 1. Cutaway View Showing Preformed FIE in Place

5. Two external layer applications of DuPont RK-692.

6. Lead peroxide-cured polysulfide applied internally.

It was concluded that external coatings were not satisfactory because a tight fit was required and that this could be lost in the field when chamber wear and tolerances occurred. The best system of the six candidates was the lead-peroxide-cured polysulfide coating applied internally.

In January 1973, representatives of Frankford Arsenal conferred with the contractor and jointly proposed an extension of the investigation of case coating materials designed to eliminate case burn-through.[4] The first phase of the program involved the investigations of the following candidate formulations:

1. Lead peroxide-cured polysulfide

    a. Without additives

    b. With Cab-O-Sil filler

    c. With ammonium sulfate filler

    d. With carbon black filler

2. Thiokol Formulation TN-L-3011

    a. Without additives

    b. With Cab-O-Sil filler

    c. With ammonium sulfate filler

    d. With varying amounts of carbon black filler

3. Elastothane 640 compositions

Ammonium sulfate was suggested as a candidate filler since it decomposes with a large exotherm in the combustion zone of certain propellant compositions. This large capacity to absorb heat in a combustion zone was considered a possible aid in the protection of aluminum cases during firing.

Thiokol formulation TN-L-3011 is based on a special temperature-sensitive curing system. It can be mixed and held in an uncured state for periods as long as a month and then heated by 150° F to initiate the curing process. The polyurethane composition (Elastothane 640) was selected for examination because of its excellent physical properties.

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[4] "Proposal for Evaluation of Materials to Provide an Insulation Sleeve for 6.00 mm Aluminum Cartridge Cases," Thiokol Proposal No. EP301-73, 19 January 1973.

The following were target properties:

1. Specific gravity greater than 1.04

2. cost of less than \$.17/in.^{3} (\$.01/cm^3)

3. Tensile strength greater than 300 psi and elongation greater than 300 percent.

Under the second phase of the program, the best candidate composition was to be selected and installed in 1000 aluminum cases for evaluation by Frankford Arsenal.

Between the time of submission of the proposal and the award of contract, technical effort at Frankford Arsenal resulted in the development of the Flexible Internal Element (FIE) cup concept, which involves the fabrication of cups of polymeric material, and a specially designed automatic rotary FIE insertion machine. The cups, which have a larger diameter than the case mouth, are folded and then inserted into the case, where they unfold and conform to the outline of the case interior against the web surface (Figure 1). This program was adjusted accordingly and FIE cups were fabricated by Thiokol Corporation for insertion by Frankford Arsenal.

The properties of compositions for FIE cups which were considered to be of importance were:

1. Toughness (tear strength)

2. Thermal stability

3. Elastomeric character

4. Insulation capacity

TECHNICAL RESULTS

Initial Evaluation of Candidate Compositions

The initial evaluation consisted of the preparation of ASTM slabs of the compositions and the determination of tensile properties, Shore A hardness, tear strength (Die C) and density. The three general types of compositions, (1) Lead Peroxide-Cured Polysulfide Compositions, (2) Thiokol Composition TN-L-3011, and (3) Polyurethane Compositions are discussed as follows.

Lead Peroxide-Cured Polysulfide Compositions
(Table I)

The polysulfide composition (Sample P1) examined under the previous program as an interior coating did not exhibit the target physical properties desired under this program. An effort was directed toward the improvement of those properties. Increasing Thermax percentage to 10 (Sample P18), 20 (Sample P10), and 30 (Sample P13) resulted in improvement in physical properties with target elongation and stress levels being exceeded in the latter two samples. Of note is the significant increase in tear strength at the 30 percent level of Thermax. The best physical properties (with respect to target values) with the carbon black SRF #3 were obtained at the 20 percent by weight level (Samples P2, P2a and P2b), but the processing of the compositions was much more difficult than that of Thermax-containing compositions because of viscosity.

When Cab-O-Sil was substituted for Thermax at a 5.3-percent level, the formulation was too viscous. At a 2.7-percent level (Sample P3), physical properties did not meet target levels. In order to determine its effect in test firings, however, Cab-O-Sil was added to a Thermax-containing composition (Sample P12).

The addition of ammonium sulfate at a 5.3 percent level (Sample P4) resulted in a loss in physical properties, and this was accentuated at the 10 and 20 percent levels (Samples P4a and P4b). To determine its possible effect, however, it was added at a five percent level in a Thermax-containing composition (Sample P15).

The technique of using milled stock was investigated by preparing Sample P17. The components were combined with solid Thiokol ST polysulfide rubber by milling, and the cups were prepared by press molding at 10,000 psi and 325° F for seven minutes. This sample was selected for the firing tests.

Thiokol Composition TN-L-3011
(Table II)

The basic formulation contains 10.60 percent Thermax (Formulation L1). Substitution of SRF Black increased stress, hardness, and tear strength but processing became difficult (Formulation L2). Increasing the Thermax level to 20 percent resulted in a stress level of 395 psi and elongation of 420 percent (Formulation L5). Cab-O-Sil (Formulation L3) and ammonium sulfate (Formulation L4) were substituted for part of the Thermax. Processing life was no problem with this formulation, but curing time was 72 hours at 150° F. Effort to decrease processing time at higher temperatures resulted in a poor cure. One sample, (Formulation L5), was submitted for firing to test the effect of the composition components.

TABLE I.
Lead Peroxide-Cured Polysulfide Compositions

Sample	P1	P2	P2a	P2b	P3	P4	P4a
LP 32	80.5	68.0	76.5	59.5	82.7	80.5	76.5
C5500 Paste	14.2	12.0	13.5	10.5	14.6	14.2	13.5
Thermax	5.3						
SRF #3 Black		20.0	10.0	30.0			
Cab-O-Sil					2.7		
Ammonium Sulfate						5.3	10.0
Density, g/cm^3	1.39	1.35	1.30	1.40	1.03	1.17	1.26
Shore A Hardness	40	60	50	58	46	42	38
Stress, psi	123	340	171	470	123	92	70
Elongation, %	205	330	240	240	210	180	210
Tear, pli (die c)	44	56	60	153	49	33	25
Sample	**P4b**	**P10**	**P12**	**P13**	**P15**	**P17**	**P18**
LP 32	68.0	68.0	68.0	59.5	59.5		76.5
C5500 Paste	12.0	12.0	12.0	10.5	10.5		13.5
Ammonium Sulfate	20.0				5.0		
Thermax		20.0	18.0	30.0	25.0		10.0
Cab-O-Sil			2.0				
Thiokol ST						70.43	
Lime						0.70	
Zinc Peroxide						3.52	
Stearic Acid						0.70	
Sterling Black S						24.65	
Density, g/cm^3	1.28	1.38	1.28	1.41	1.66	1.38	1.37
Shore A Hardness	42	45	54	60	38	60	40
Stress, psi	88	264	240	310	244	790	158
Elongation, %	95	264	293	370	320	375	210
Tear, pli (die c)	23	92	85	120	88		62

TABLE II.
Thiokol Formulation TN-L-3011

	Formulation				
	L1	L2	L3	L4	L5
TN-L-3011	89.40	89.40	89.40	89.40	80.00
Thermax	10.60		8.10	5.30	20.00
SRF No. 3		10.60			
Cab-O-Sil			2.50		
$(NH_4)_2SO_4$				5.30	
Density, g/cm^3	1.79	1.61	1.70	1.69	1.71
Shore A Hardness	42	67	62	55	40
Stress, psi	114	213	174	107	395
Elongation, %	280	245	365	150	420
Tear, pli (die c)	41	64	77	42	132

Polyurethane Compositions
(Table III)

Elastothane 640, a millable polyurethane, was proposed for application in cylinder form. Its properties, in cured form, are listed in Table III (Sample E7). Elastothane 625 is also a millable polyester polyurethane gum (Sample E8). Both formulations were sulfur-cured and ZC-456 and cadmium stearate functioned as activators and benzothiazyl disulfide (MBTS) and mercapto-benzothoazole functioned as accelerators. The transition to FIE cups, however, indicated the desirability of using castable compositions.

Castable versions of Elastothane 640 compositions were prepared through the utilization of a fluid isocyanate-terminated polyester, Solithane 291 (Sample E1). The addition of Thermax at a ten percent level resulted in an increase in tear strength (Sample E3). When Cab-O-Sil (Sample E2) and ammonium sulfate (Sample E4) were added, difficulties were encountered with gassing, indicating that these components must be thoroughly dried before addition. Another curative for Solithane 291, Isonol 93, was examined (Sample E5).

A castable isocyanate-terminated polyether (Adiprene L) was examined as Sample E6. It showed excellent tear strength, 432 pounds per linear inch (pli), but this type of formulation is very difficult to degas.

Another type of castable polyurethane under examination was that derived from a fluid hydroxy-terminated polybutadiene. This type is expecially attractive because of cost (about \$.50/lb) and because of

TABLE III.
Polyurethane Formulations

Sample	670-7	E1	E2	E3	E4	E5	E6
R45	233.0						
TDI	72.9						
C_6H_5COCl	0.14						
Solithane 291		68.03	65.39	79.23	79.23	93.46	
TIPA/TMP		3.17	3.07	2.65	2.85		
Benzoflex 988		8.80	6.80	7.92	7.92		
Cab-O-Sil			3.00				
Thermax				10.00			
Ammonium Sulfate					10.00		
Isonol 93						6.54	
Adiprene L							91.74
1,4-Butanediol							6.26
Density, g/cm^3		1.22		1.25	1.26	1.22	
Shore A Hardness	Fluid	55		60	54	60	
Stress, psi	Pre-Polymer	1930	Gassed	1400	1300	2000	3260
Elongation, %		490		497	470	465	435
Tear, pli (die c)		146		195	210	10	432

Sample	E7	E8	E10	E11	E12	E13	E14
Elastothane 640		76.92					
Elastothane 625	76.92						
TE-75	0.77	0.77					
Adaphax #758	7.69	7.69					
FEF Black	7.69	7.69					
MBTS	3.08	3.06					
MBT	1.54	1.54					
ZC 456	0.77	0.77					
Cd Stearate	0.39	0.39					
Sulfur	1.15	1.15					
R45S			60.10				
TDI			3.67			3.70	
DBTDL			0.18		0.04		
Thermax			36.05				
R45				33.03		48.03	
Isonol C100				5.52	17.53		
Isonate 143L				11.41			
Stannous octoate				0.04		0.50	
Sample 670-7					62.41		57.50
Calcene TM						46.03	
Glyceryl triricinoleate							42.50
Density, g/cm^3	1.05	1.11	1.14		1.02		
Shore A Hardness	60	57	57	60*	95*	55*	55
Stress, psi	3630	3600	1130*	690*	3140*	350*	
Elongation, %	490	520	460*	330*	495*	320*	
Tear, pli (die c)	350	320	130*	65*	295*	53*	

*Vendor's Properties

its improved behavior at low temperatures as compared to polyesters and polyethers. The basic structure is designated as R45; another type is CS-15, which is a hydroxy-terminated butadiene-styrene copolymer. The latter was combined with toluene diisocyanate (TDI) as curative, dibutyltin dilaurate (DBTDL) as cure catalyst, and Thermax as filler in Formulation E10. This type of reaction has been designated as "one-step." The basic R45 was cured with Isonate 143L in Formulation E11 with Isonol C-100 (N, N-bis(2-hydroxypropyl)aniline) as low molecular weight diluent and stannous octoate as cure catalyst. Calcium carbonate (Calcene TM) was added as filler in Formulation E13. Sample 670-7 is a fluid isocyanate-terminated R45 which is used in the preparation of gumstocks by the "two-step" process. This fluid prepolymer was cured with Isonol C-100 in Formulation E12 and glyceryl triricinoleate (castor oil) in Formulation E14.

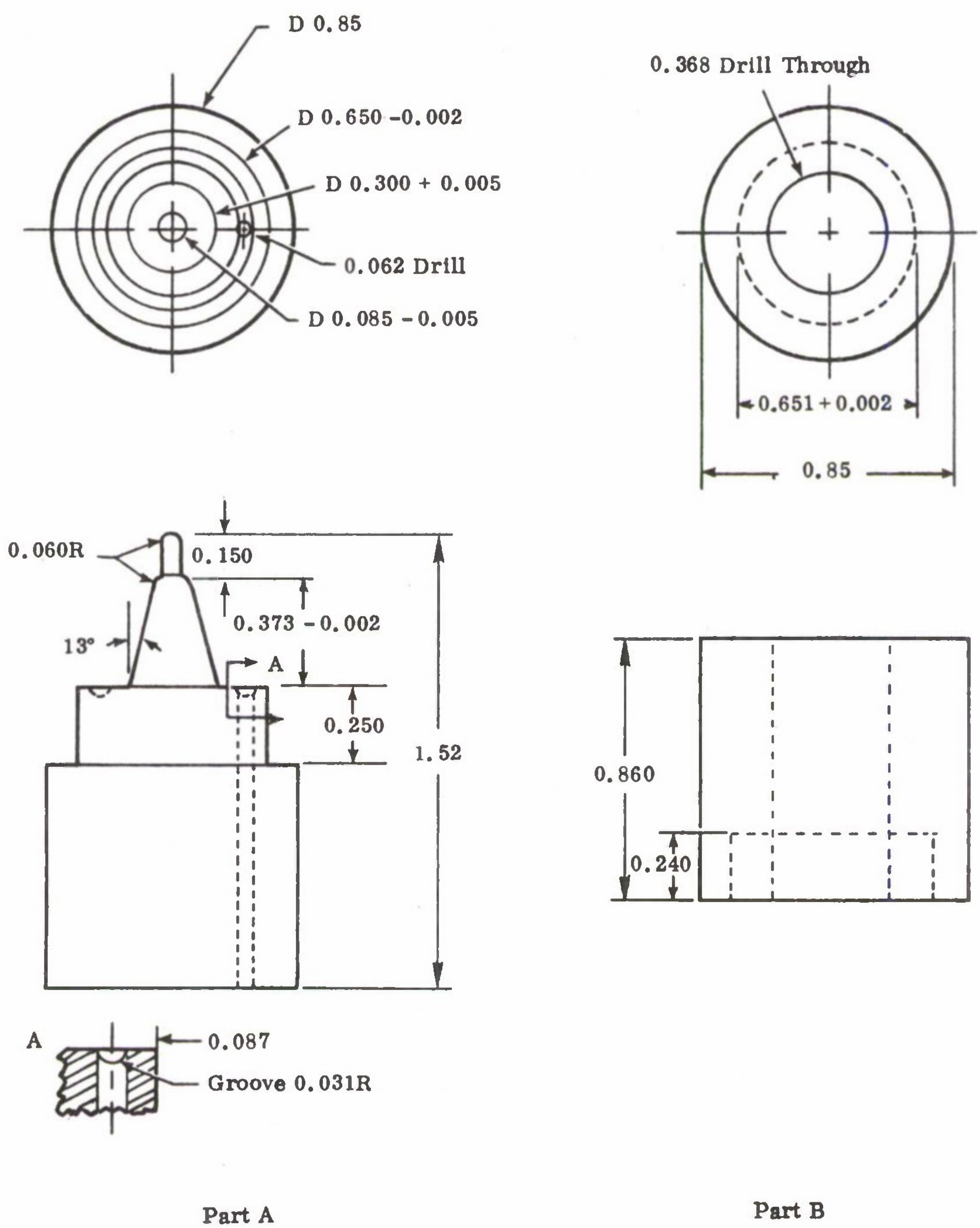
Preparation of Initial Samples for Test Firing

A Thiokol single mold (Figure 2) was used to preform the approved Frankford Arsenal FIE sealing cup design (Figure 3). Fabrication of the mold involved the use of the lower 1/3 portion of a 5.56 mm case, which was anchored in the mold with adhesive EA946 (HYSOL).

First Test Series

To simulate case damage that could occur as a result of field use, the outside surface of the cases were grooved longitudinally (Figure 4). The test conditions were as follows:

1. Test Date: 5 April 1974
2. Preformed Sealing Cup (Figure 3)
3. Aluminum Case, 5.56 mm (D10542721)
4. Groove Depth (Figure 4)
5. Primer, FA41 (C10534279)
6. Ball Bullet, M193 (C10524197)
7. Propellant: Weight - 24.5 grains; Blend 4:1 - WC846 (80%), WC680 (20%)
8. Mann Test Barrels Nos. 94, 201, 205 (5.56 mm)
9. Universal Receiver, FA30
10. Test Temperature: Ambient
11. Velocity Screens Set at 5' and 20' from Muzzle.



Note: Parts A and B should be fabricated as matched parts of mold assembly.

Figure 2. Thiokol Single Mold Details

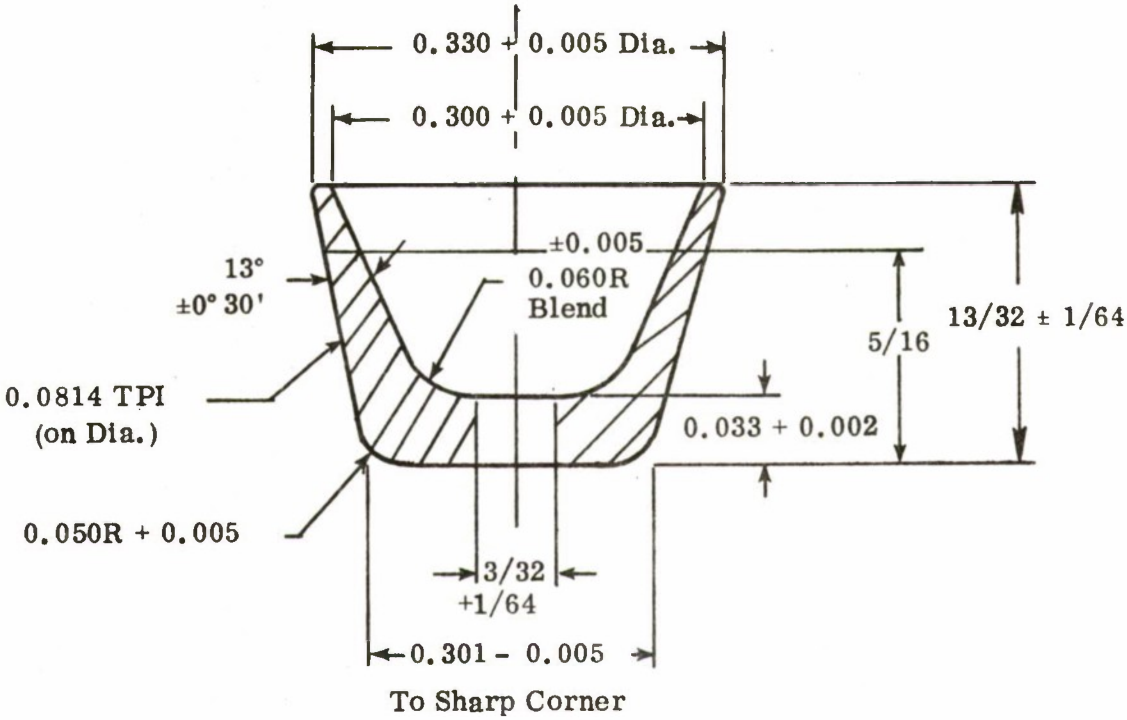


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Figure 3. Detail of FIE Sealing Cup

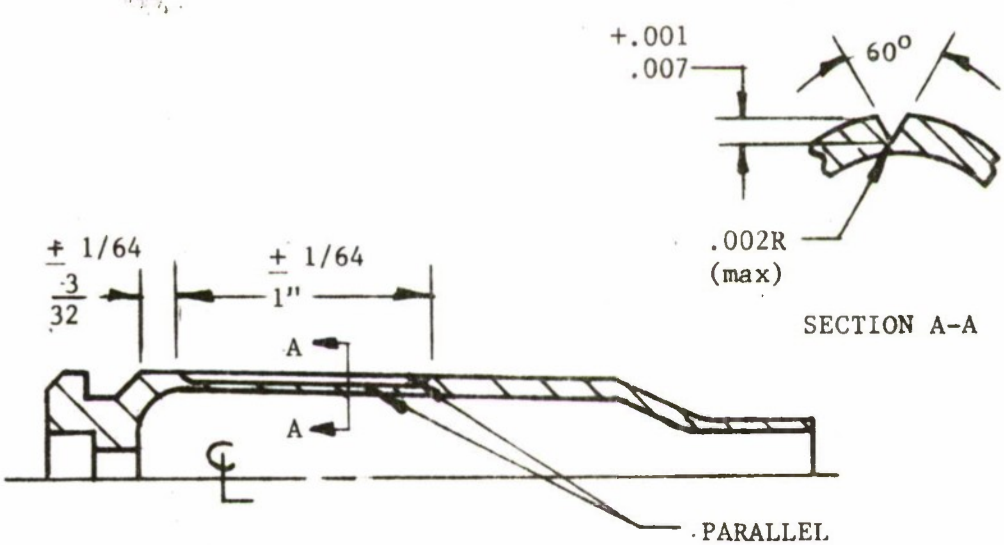

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Figure 4. Groove Dimensions for Induced Failure Test

Legend of Test Firing Observations

Insertion Method

Mech. - Mechanical (Frankford)
Man. - Manual (Elkton)

Ease of Insertion

ND - No difficulty
VD - Very difficult
MD - Moderately difficult

Breech Flash

N - None
S - Small
M - Medium
L - Large
Sp - Sparks

Cup Behavior During Firing

M - Cup moved
CF - Collapsed during firing
N - No cup movement

Erosion Type (Figure 5)

N - None
I, II, III

These tests resulted in the following observations and conclusions:

1. The polysulfide formulations P10 and P18 should be subjected to larger scale testing.

2. Shore A hardness should not exceed 50. Greater damage to cups can occur during insertion or insertion is not possible.

3. The milled stock specimens were too stiff for ready insertion; modifications of the formulation are possible to produce softer samples.

Three test barrels were used for this series. A typical barrel erosion is shown in the photograph included in Appendix A.

Details of individual firings are presented in Table IV. The results of this first test firings are summarized in Table V. Types and locations of erosion are shown in Figures 5 and 6. Figures 7 through 22 present photographs of the cases, which include x-rays before and after firing and an exterior view after firing. Enlarged photographs (2x) of FIE cups after firing are included to show their condition with different test results.

TABLE IV. FIE Cup Evaluation (First Test Series)

Test Group	Round	Formulation	Cup Wt. for Test Group, (avg gr.)	Insertion Method	Ease of Mechanical Insertion	FIE Gap[2] AFTER INSERTION (IN.)	Breech Flash	Erosion Type[3]	Cup[4] Behavior During Firing	Muzzle Velocity, (fps)	Remarks
A	1	P10	5.151	Mech.	ND	0	N	N	M	--	
	2			Mech.		0.005	N	N	M	3216	Damaged during insertion.
	3			Mech.		0	N	N	M	3261	
	4			Mech.		0.08					Damaged, not fired.
B	1*	P10	--	Man.		0.010	See Note 1.				Reduced cup weight (4.5 grains)
	2			Man.		Slight	L	II	CF	3202	Reduced cup weight.
	3*			Man.		0.010					Reduced cup weight, see Note 1.
	4			Man.		Slight	L	I	M	3201	Reduced cup weight.
C	2	P10	--	Man.		0	N	N	M	3211	
	3			Man.		0	N	N	M	3213	Damaged during insertion.
	1			Man.		0.30	N	N	M	3238	This group inserted partially cured, then fully cured in case.
	7			Man.		0.30	N	I	M	3190	
	5*			Man.		0	See Note 1.				Damaged during insertion.
D	3	P13	5.221	Mech.	VD	0.010	S	I	M	3184	
	4			Mech.	VD	0	N	N	M	3275	
	2			Mech.	VD	0	Sp	II	M	3233	
	1			Mech.	VD	0	L	I	M	3213	
	5			Mech.	VD	0.910					
E	3	P12	5.392	Mech.	ND	0	N	I	M	3246	
	4			Mech.	ND	0	N	I	M	3227	
	1			Mech.	ND	0.670					
	2			Mech.	ND	0.880					
F	1	P15	5.567	Mech.	MD	0	Sp	I	M	3225	
	4			Mech.	MD	0	Sp	-	-	3234	
	2			Mech.	MD	0.010	S	II	M	3261	
	3			Mech.	MD	0.850					Gap too large for firing.
	5			Mech.	MD	0.910					Gap too large for firing.
G	1	P18	4.976	Mech.	ND	0	N	N	M	3191	Cup folded.
	2			Mech.	ND	0	N	N	M	3223	
	3			Mech.	ND	0	N	N	M	3276	
	4			Mech.	ND	0.870					Gap too large for firing.
H	3	E1		Man.		Slight	Sp	II	M	3270	
	5			Man.		0	N	I	M	3230	
	12			Man.		0	N	I	M	3248	
I	2	E1	4.389	Mech.	MD	0	N	N	-	3184	
	3			Mech.	MD	0	N	II	M	3269	
	4			Mech.	MD	0	N	II	-	3205	
	5			Mech.	MD	0	N	I	-	3203	
	6			Mech.	MD	0	N	M	-	3260	
	1			Mech.	MD	0.05	L	II	-	3201	

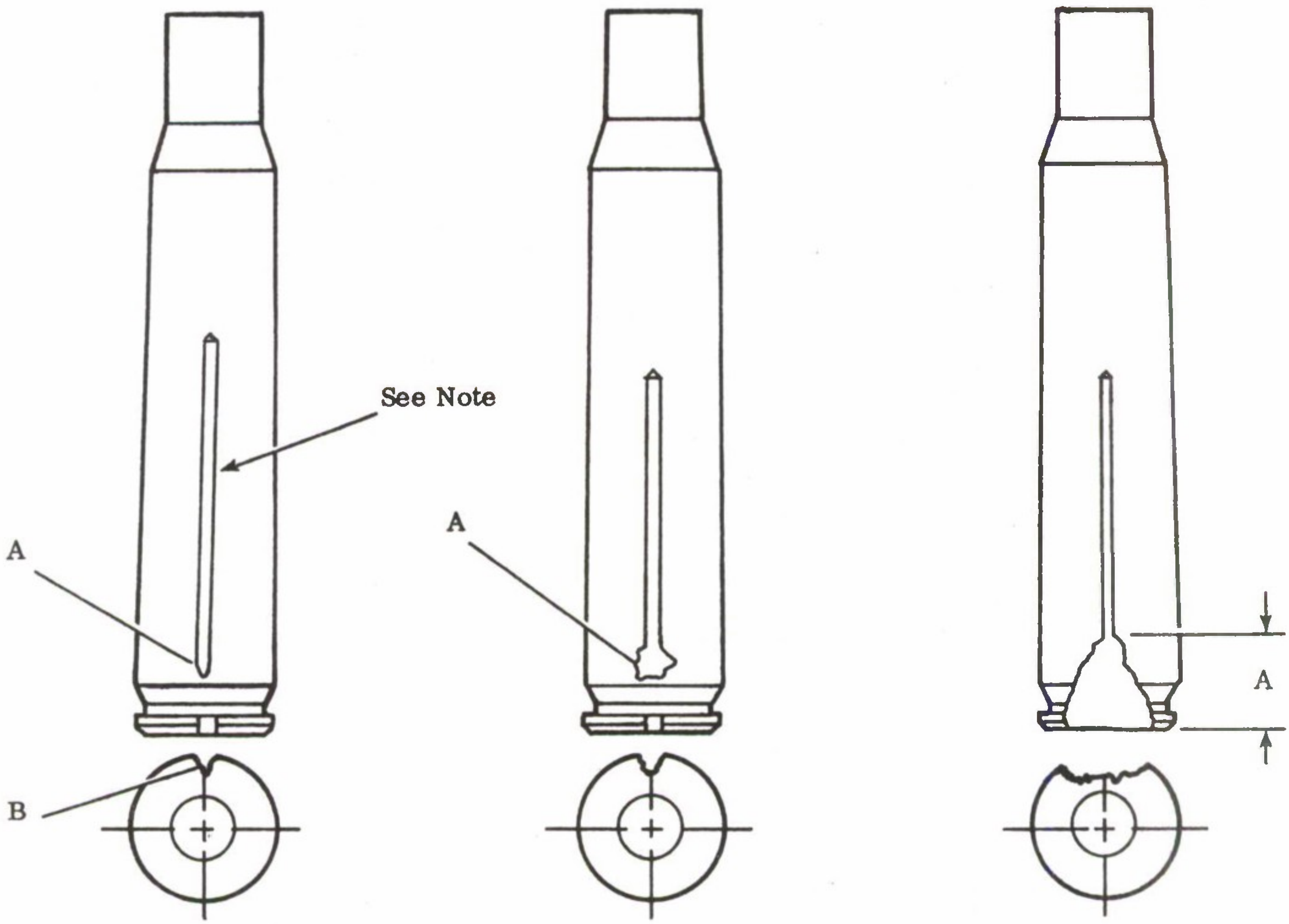
TABLE IV. FIE Cup Evaluation (First Test Series) - Cont'd

Test Group	Round	Formulation	Cup Wt. for Test Group, (avg gr.)	Insertion Method	Ease of Mechanical Insertion	FIE Gap AFTER INSERTION (IN.)[2]	Breech Flash	Erosion Type[3]	Cup Behavior During Firing[4]	Muzzle Velocity, (fps)	Remarks
J	1	E3	4.613	Mech.	MD	0	Sp	I	-	3219	
	2			Mech.	MD	0	Sp	I	M	3233	
	3			Mech.	MD	0	L	II	M	3250	
	4			Mech.	MD	0	L	III	CF	3201	
	5*			Mech.	MD	0					See Note 1.
K	1	E7	5.222	Mech.	VD	0	M	II	-	3214	
	2			Mech.	VD	0	M	II	-	3192	
	3			Mech.	VD	0					
	4			Mech.	VD	0					
	5										Could not insert.
	6										Could not insert.
	7										Could not insert.
L	1	E8	5.334	Mech.	VD	0	L	III	-	3137	
	4			Mech.	VD	0	L	II	-	3210	
	2			Mech.	VD	0.020					See Note 1.
	3			Mech.	VD	0.005					See Note 1.
	5			Mech.	VD	0.020					See Note 1.
	6										Could not insert.
M	1	E9	3.611	Mech.	ND	0	M	II	-	3243	
	2			Mech.	ND	0	N	N	-	3243	
	3			Mech.	ND	0	L	I	-	3248	
	4			Mech.	ND	0	L	I	-	3248	
	5			Mech.	ND	0	N	I	-	3216	
N	1	E10	4.799	Mech.	ND	0	N	II	N	3256	
	3			Mech.	ND	0	L	II	N	3246	
	4			Mech.	ND	0	L	I	N	3284	
	2										Cup not seated.
O	1	E13	4.675	Mech.	ND	0	Sp	I	M	3352	
	2			Mech.	ND	0	Sp	I	M	3241	
	3			Mech.	ND	0	L	II	M	3313	
	4			Mech.	ND	0	Sp	N	M	3281	
P	1	L5	6.607	Mech.	MD	Slight	L	II	M	3199	Damaged during insertion.
	2			Mech.	MD	0.005	L	III	M	--	
	3			Mech.	MD	Slight					See Note 1.
Q		P17	6.699								Could not insert.
R		E12	3.618								Could not insert.
S		E14	3.81		ND						No cups seated.

Notes: 1. Not fired because of poor results with other rounds.
2. Gap represents distance between cup base and web face.
3. Refer to Figure 5.
4. Refer to Figure 23.

TABLE V.
Summary of First Test Firings

Test Group	Formulation	Identification	Remarks and Results
A	P10	LP32-C5500-20% Thermax	No erosion; selected for further testing.
B	P10		Reduced weight cups to facilitate insertion (4.5 grains); erosion occurred.
C	P10		Inserted into cases partially cured, then cure completed in cases; some erosion.
D	P13	LP32-C5500-30% Thermax	Apparently too stiff for facile insertion; erosion occurred.
E	P12	P10 with 2% Cab-O-Sil	Erosion occurred
F	P15	P13 with 5% ammonium sulfate	Erosion occurred
G	P18	LP32-C5500-10% Thermax	No erosion; selected for further testing
H	E1	Sol. 291-TIPA/TMP-Benzoflex 988	Erosion occurred
I	E1		Inserted into cases partially cured, then cure completed in cases; erosion occurred.
J	E3	E1 with 10% Thermax	Erosion occurred
K	E7	Pressure/heat cured milled Sol. 625	Erosion occurred
L	E8	Pressure/heat cured milled Sol. 640	Erosion occurred
M	E9	CS-15 cured with TDI, Cab-O-Sil filler	Erosion occurred
N	E10	CS-15 cured with TDI, Thermax filler	Erosion occurred
O	E13	R45 cured with TDI, Calcene TM filler	Erosion occurred
P	L5	TN-L-3011	Erosion occurred
Q	P17	Pressure/heat cured milled Thiokol ST	Could not be inserted
R	E12	TDI-capped R45 cured with Isonol C-100	Could not be inserted
S	E14	TDI-capped R45 cured with Glyceryl triricinoleate	No cups seated

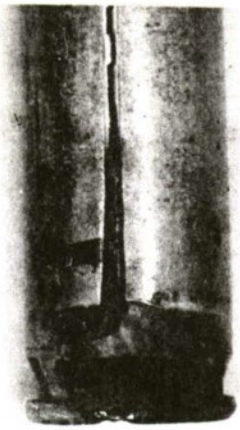


Type I (Linear)	Type II (Fan)	Type III (Conical)
A-In lower 1/3 body section above extractor groove	A-In lower 1/3 body section above extractor groove	A-In lower 1/3 body section extending into extractor groove and rim
B-Extending into rim	B-Extending into rim	

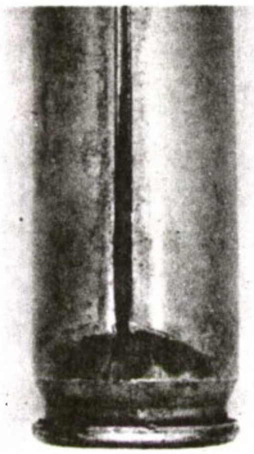
Note: For groove dimensions see Figure 4.

Figure 5. Type and Location of Erosion in Aluminum Cartridge Cases (Used for induced failure only)

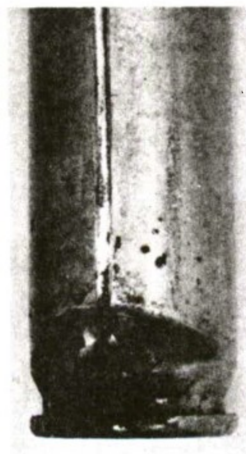
Type I W/O "B"



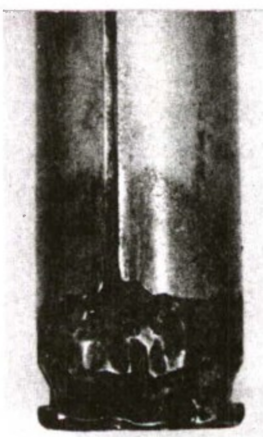
Type I W/"B"



Type II W/O "B"



Type II W/"B"



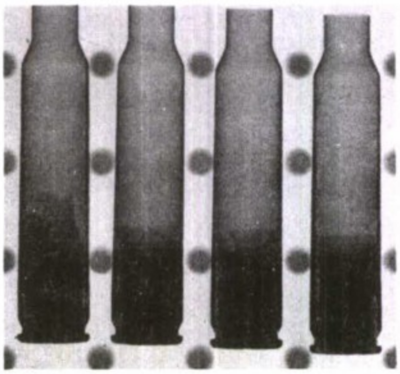
Type III

Figure 6. Examples of Erosion Types

Test Group A

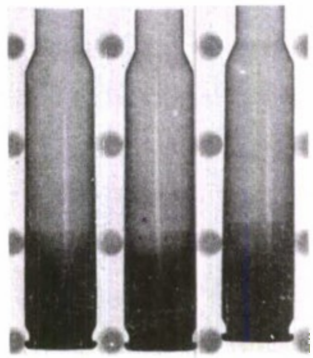
Formulation: P10

LP-32	68.0
C5500	12.0
Thermax	20.0



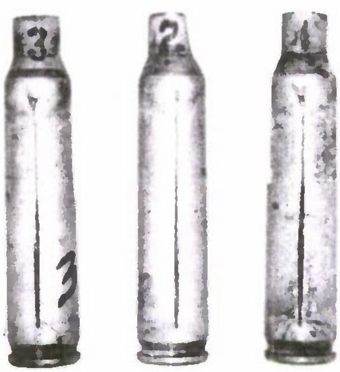
4 3 2 1

Case X-Ray Before Loading



3 2 1

Case X-Ray After Firing



3 2 1

Case Exterior After Firing

3 2 1

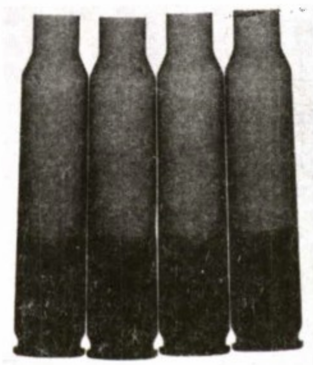
FIE Cups After Firing (2X)

Figure 7. Test Group A, Formulation P10

Test Group B

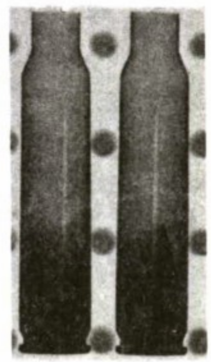
Formulation: P10

LP-32	68.0
C5500	12.0
Thermax	20.0



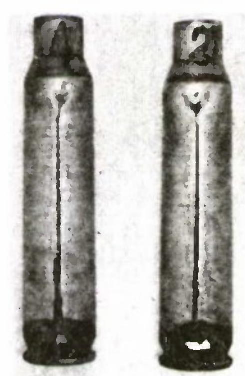
4 3 2 1

Case X-Ray Before Loading



4 2

Case X-Ray After Firing



4 2

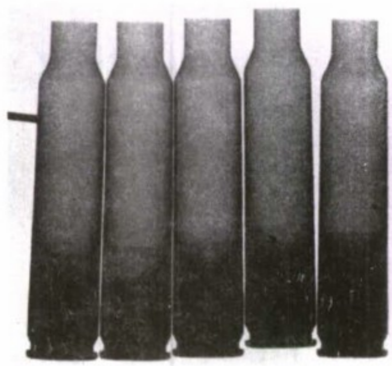
Case Exterior After Firing

Figure 8. Test Group B, Formulation P10

Test Group C

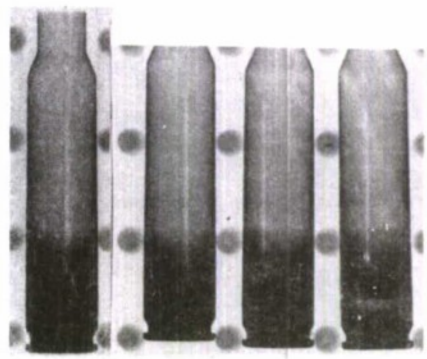
Formulation: P10

LP-32	68.0
C5500	12.0
Thermax	20.0



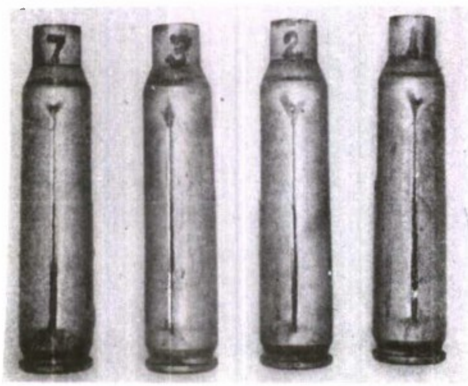
7 5 3 2 1

Case X-Ray Before Loading



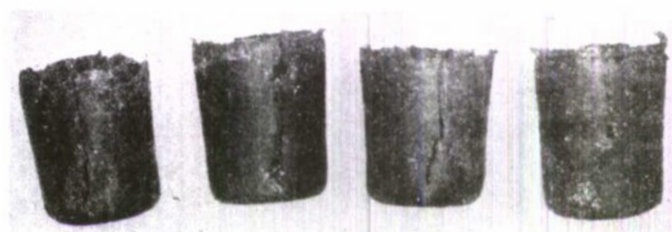
1 2 3 7

Case X-Ray After Firing



7 3 2 1

Case Exterior After Firing



7 3 2 1

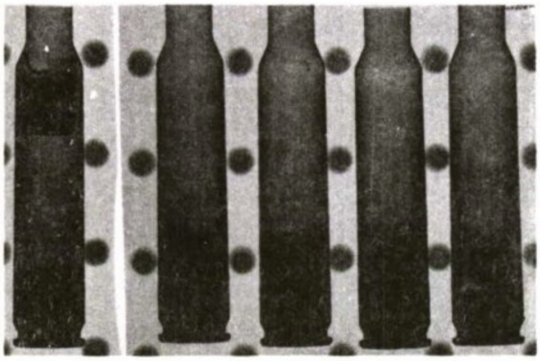
FIE Cups After Firing (2X)

Figure 9. Test Group C, Formulation P10

Test Group D

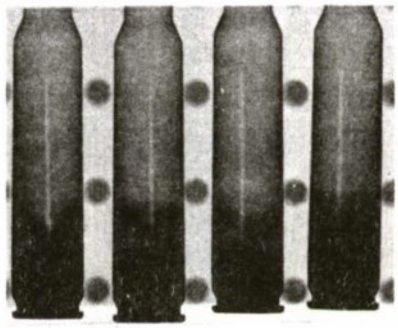
Formulation: P13

LP-32	59.5
C5500	10.5
Thermax	30.0



5 4 3 2 1

Case X-Ray Before Loading



1 2 3 4

Case X-Ray After Firing

3 4 2 1

Case Exterior After Firing

3

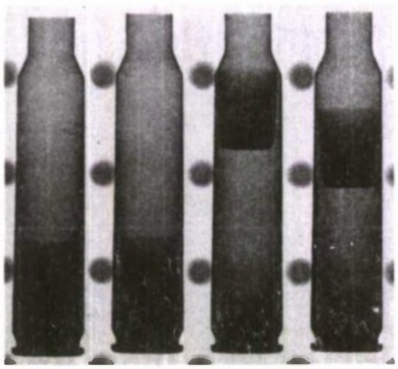
FIE Cup After Firing (2X)

Figure 10. Test Group D, Formulation P13

Test Group E

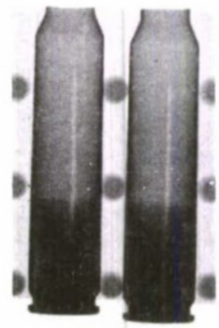
Formulation: P12

LP-32	68.0
C5500	12.0
Thermax	18.0
Cab-O-Sil	2.0



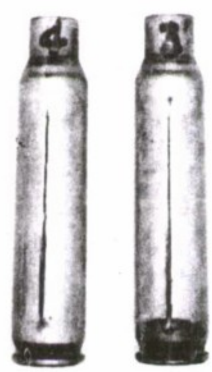
4 3 2 1

Case X-Ray Before Loading



4 3

Case X-Ray After Firing



4 3

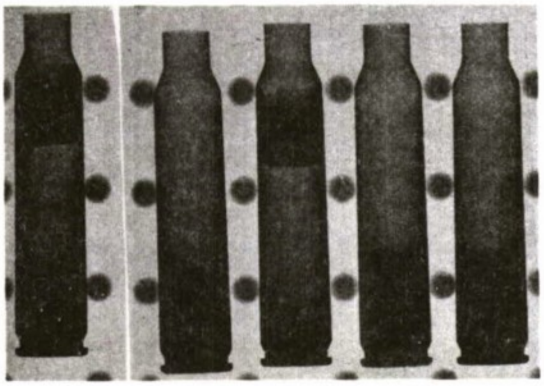
Case Exterior After Firing

Figure 11. Test Group E, Formulation P12

Test Group F

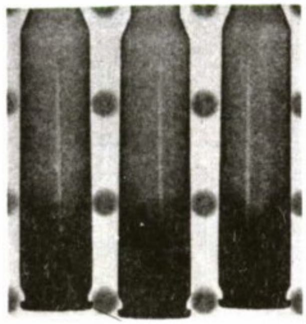
Formulation: P15

LP-32	59.5
C5500	10.5
Thermax	25.0
$(NH_4)_2SO_4$	5.0



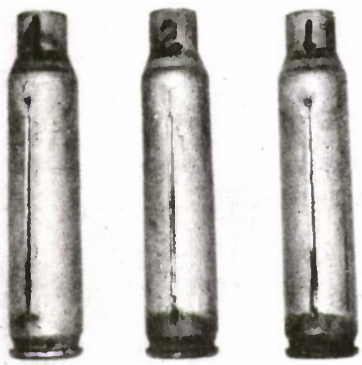
5 4 3 2 1

Case X-Ray Before Loading



4 2 1

Case X-Ray After Firing



4 2 1

Case Exterior After Firing

2

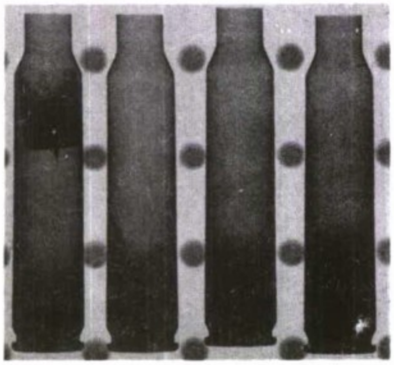
FIE Cup After Firing (2X)

Figure 12. Test Group F, Formulation P15

Test Group G

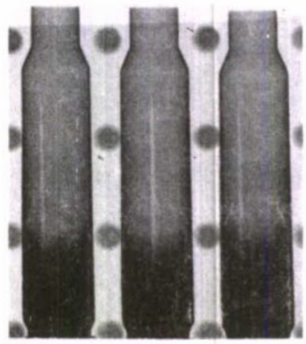
Formulation: P18

LP-32	76.5
C5500	13.5
Thermax	10.0



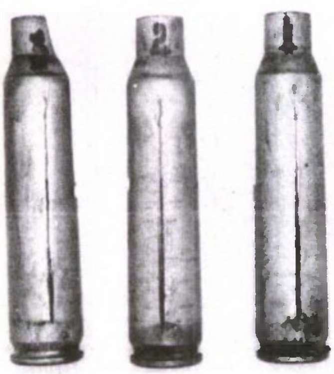
4 3 2 1

Case X-Ray Before Loading



3 2 1

Case X-Ray After Firing



3 2 1

Case Exterior After Firing

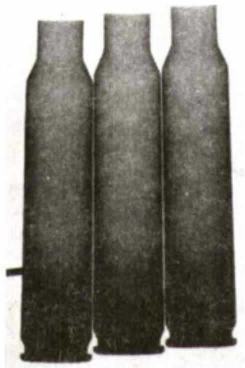
3 2 1

FIE Cup After Firing (2X)

Figure 13. Test Group G, Formulation P18

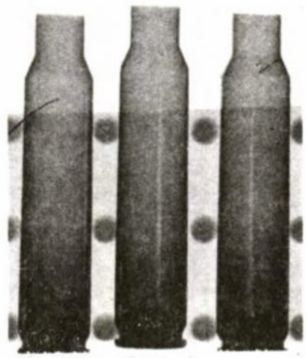
Test Group H

Formulation:	E1
Solithane 291	88.03
TIPA/TMP	3.17
Benzoflex 988	8.80



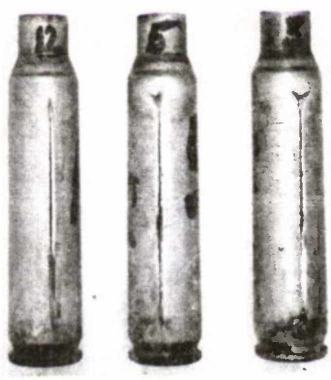
12 5 3

Case X-Ray Before Loading



12 5 3

Case X-Ray After Firing



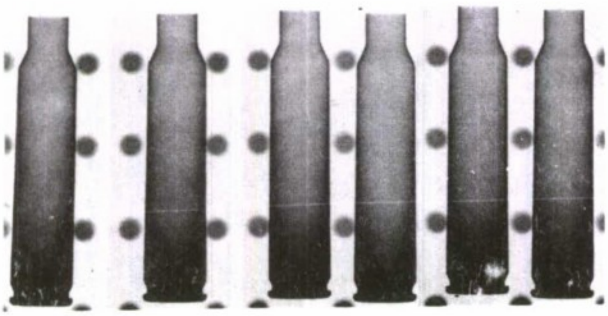
12 5 3

Case Exterior After Firing

Figure 14. Test Group H, Formulation E1

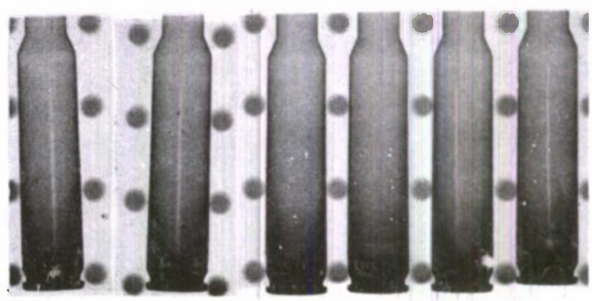
Test Group I

Formulation:	E1
Solithane 291	88.03
TIPA/TMP	3.17
Benzoflex 988	8.80



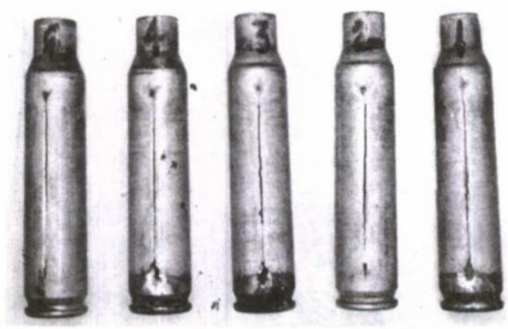
6 5 4 3 2 1

Case X-Ray Before Loading



6 5 4 3 2 1

Case X-Ray After Firing



6 4 3 2 1

Case Exterior After Firing

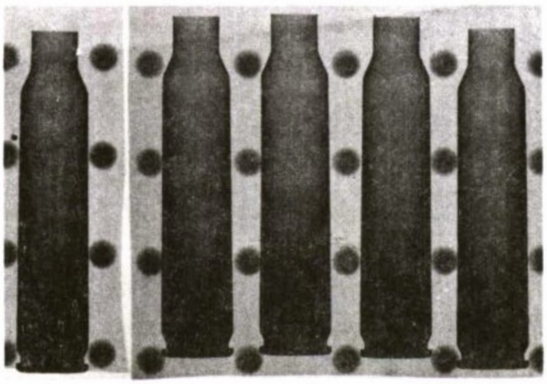
1

FIE Cup After Firing (2X)

Figure 15. Test Group I, Formulation E1

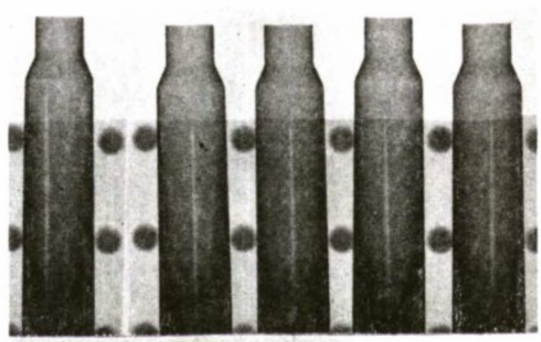
Test Group J

Formulation:	E3
Solithane 291	79.23
TIPA/TMP	2.85
Benzoflex 988	7.92
Thermax	10.00



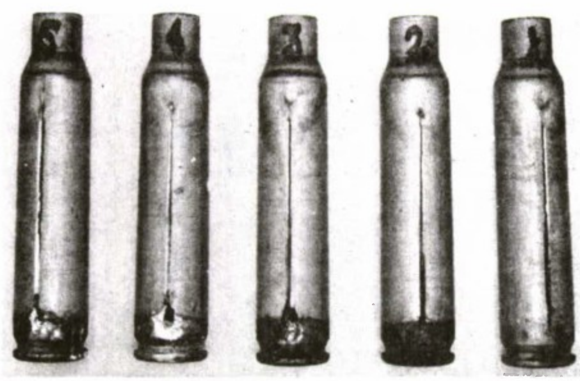
5 4 3 2 1

Case X-Ray Before Loading



5 4 3 2 1

Case X-Ray After Firing



5 4 3 2 1

Case Exterior After Firing

4

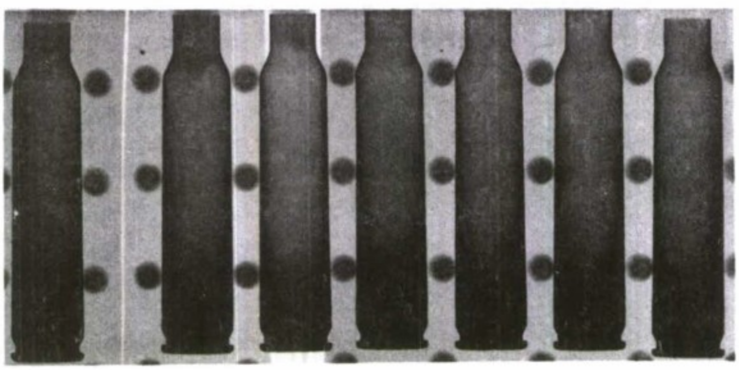
FIE Cup After Firing (2X)

Figure 16. Test Group J, Formulation E3

Test Group K

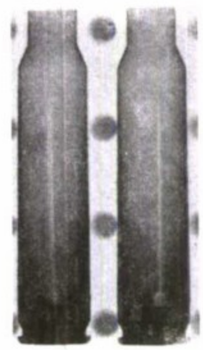
Formulation:	E7
Elastothane 625	76.92
TE-75	0.77
Adaphax 758	7.69
FEF Black	7.69
MBTS	3.08
MBT	1.54
ZC 456	0.77
Cd Stearate	0.39
Sulfur	1.15

Partially Inserted FIE Cups



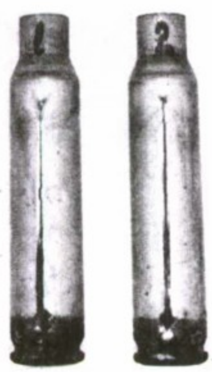
7 6 5 4 3 2 1

Case X-Ray Before Loading



2 1

Case X-Ray After Firing



1 2

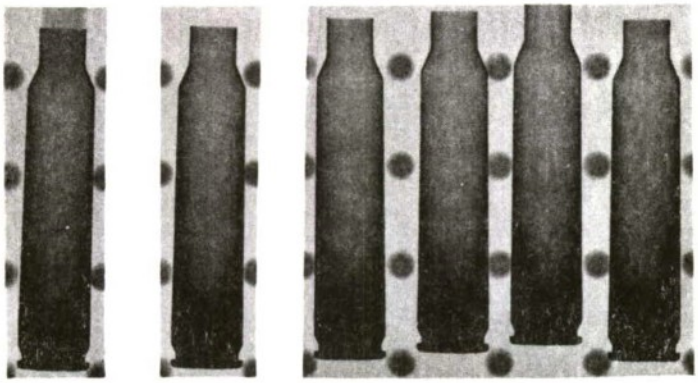
Case Exterior After Firing

Figure 17. Test Group K, Formulation E7

Test Group L

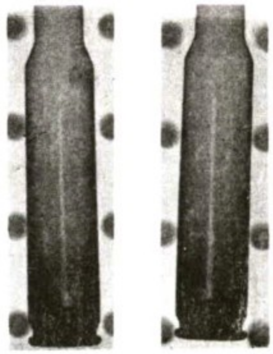
Formulation:	E8
Elastothane 640	76.92
TE-75	0.77
Adaphax 758	7.69
FEF Black	7.69
MBTS	3.08
MBT	1.54
ZC 456	0.77
Cd Stearate	0.39
Sulfur	1.15

Partially Inserted FIE Cup



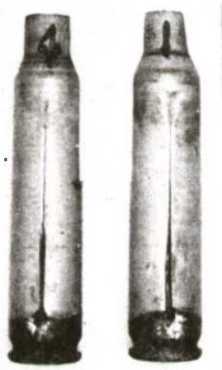
6 5 4 3 2 1

Case X-Ray Before Loading



4 1

Case X-Ray After Firing



4 1

Case Exterior After Firing

4 1

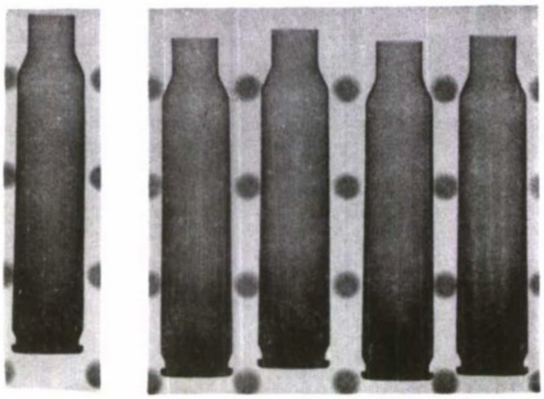
FIE Cup After Firing (2X)

Figure 18. Test Group L, Formulation E8

Test Group M

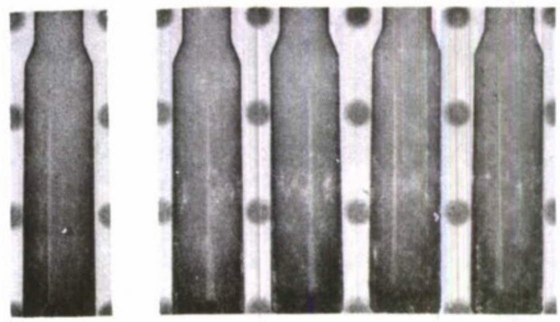
Formulation: E9

R45S	89.15
TDI	5.99
DBTDL	0.14
Cab-O-Sil	4.72



5 4 3 2 1

Case X-Ray Before Loading



5 4 3 2 1

Case X-Ray After Firing

5 4 3 2 1

Case Exterior After Firing

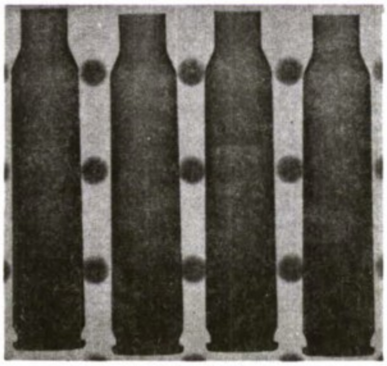
3 1

FIE Cups After Firing (2X)

Figure 19. Test Group M, Formulation E9

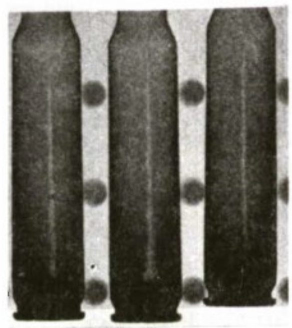
Test Group N

Formulation:	E10
R45S	60.10
TDI	3.67
DBTDL	0.18
Thermax	36.05



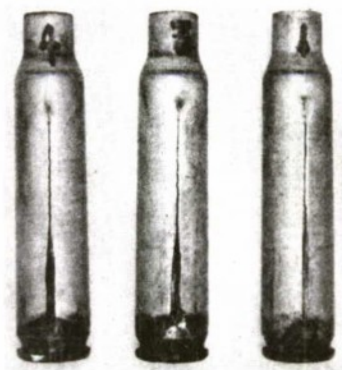
4 3 2 1

Case X-Ray Before Loading



4 3 1

Case X-Ray After Firing



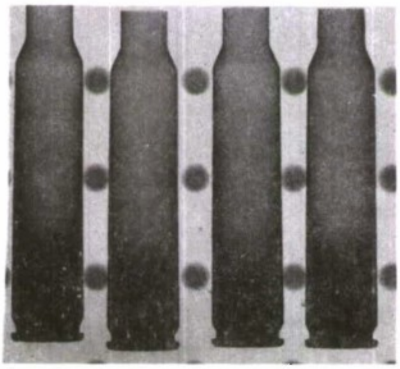
4 3 1

Case Exterior After Firing

Figure 20. Test Group N, Formulation E10

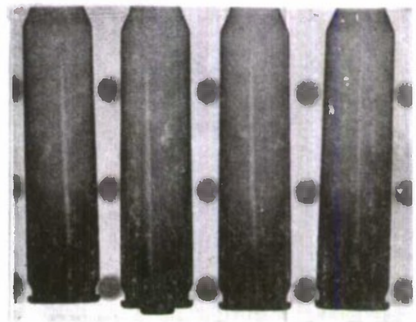
Test Group O

Formulation:	E13
R45	48.03
Sn octoate	0.50
TDI	3.70
Calcene TM	48.03



4 3 2 1

Case X-Ray Before Loading



4 3 2 1

Case X-Ray After Firing

4 3 2 1

Case Exterior After Firing

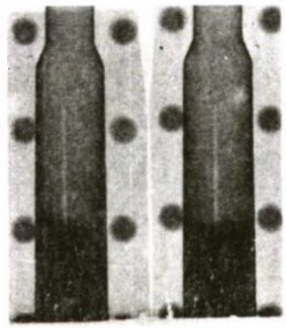
Figure 21. Test Group O, Formulation E13

Test Group P

Formulation:	L5
LP-2	42.95
$BaSO_4$	16.60
$Fe_2 O_3$	11.81
NH_4 Dichromate	4.30
Na Tetraborate	4.30
ZC-123	0.04
Thermax	20.00

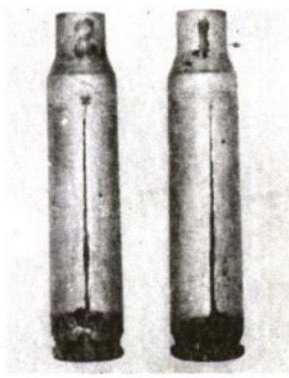
3 2 1

Case X-Ray Before Loading



2 1

Case X-Ray After Firing



2 1

Case Exterior After Firing

Figure 22. Test Group P, Formulation L5

Second Test Series

The second series of tests was made of a total of 150 samples (part of the contractual 1000 samples). Five formulation type of cups were included: P10, P18, P19, P20, and P21. The first two formulations appear in Table I; the formulations of the latter three appear in Table VI.

TABLE VI.
Polysulfide Formulations (Second Test Series)

Sample	P19	P20	P21
LP 31	62.1	69.9	---
LP 205	3.6	4.1	---
LP 370	3.3	3.7	---
LP 32	---	---	72.3
C5500 Paste	11.0	12.3	12.7
Thermax	20.0	10.0	15.0

The two polysulfide polymers, LP 205 and LP 370, were added to improve low temperature properties (if necessary). This occurs because they have different backbone structures than the basic polymer. This technique has been found effective in polysulfide composite propellants. Sample P21 was submitted to further define the Thermax level required.

The types of behavior and condition of sealing cups final position after fire are shown in Figure 23. The detailed results are presented in Tables VII to XI. Test conditions were as follows:

1. Test Date: 19 June 1974
2. Preformed Sealing Cup (Figure 3)
3. Aluminum Case, 5.56 mm (D10542721, Case Material-X7475T6
4. Groove Depth (Figure 4)
5. Primer, FA41 (C10534279) (Not crimped in place)
6. Ball Bullet, M193 (C10524197)
7. Propellant: Weight - 24.5 grains; Blend 4:1 - WC846 (80%), WC680 (20%)
8. Mann Test Barrel 5.56 mm
9. Velocity Screens Set at 5' and 20' from Muzzle
10. Test temperature: Ambient

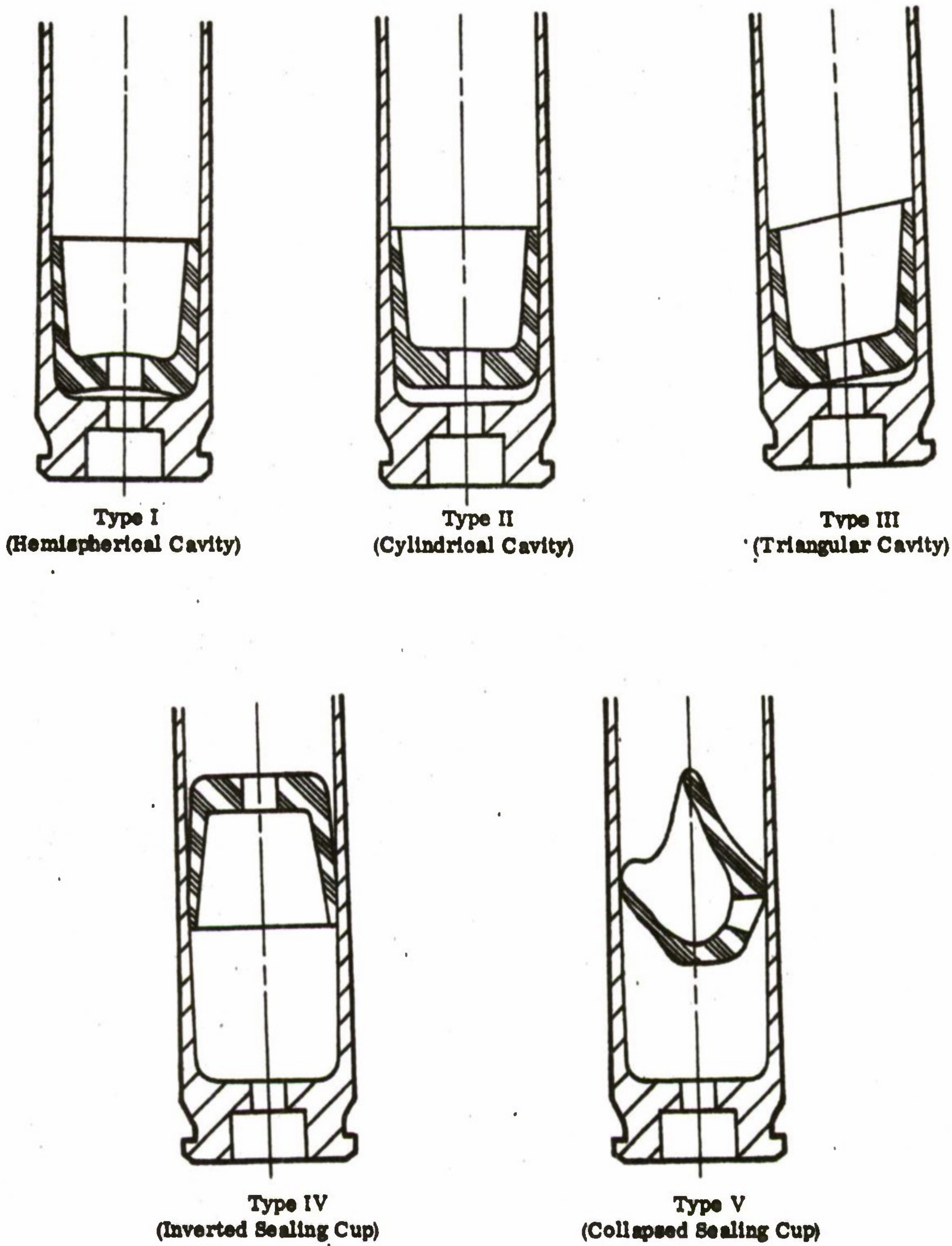


Figure 23. Reporting Condition of FIE Behavior During Insertion and After Fire

TABLE VII. Test Results of Sample P10[1,2]

Round	No. Cup Insertion Attempts	Cup Position After Insertion	FIE Gap (in.) After Insertion[6]	FIE Gap (in.) After Firing[6]	Breech Flash	Erosion Type[4]	Cup Behavior During Firing[3]	Velocity (fps)	Remarks
1	1	II	0.009	0.013	N	N	II	3234	
2	1	II	0.007	0.026	N	IIB	II	3228	
3	1	II	0.009	0.026	N	IIB	II	3195	
4	1	II	0.007	0.020	N	N	II	3206	
4A	1	V	Not Fired Collapsed Cup						See Figure 24
5	1	II	0.007	0.029	N	I	II	3218	
6	1	II	0.017	0.028	N	N	II	3229	
6A	2	II	0.007	0.017	N	N	II	3254	
7	1	II	0.005	0.017	N	N	II	3269	
8	1	II	0.004	0.026	Sp	N	II	3285	Case rupture counter-clockwise 12 to 9 o'clock
9	1	II	0.011	0.020	N	N	II	3295	
10	1	II	0.007	0.023	N	N	II	3239	270° case rupture. See Note 5.
11	1	II	0.005	0.032	N	I	II	3206	
11A	2	II	0.007	0.030	Sp	II	II	3247	Case rupture counter-clockwise 9 to 12 o'clock
12	1	II	0.003	0.040	Sp	II	II	3272	
12A	2	II	0.002	0.025	N	N	II	3235	
13	1	II	0.003	0.020	N	II	II	3277	
13A	2	II	0.004	0.030	N	N	II	3214	
13B	2	II	0.023	0.027	N	I	II	3209	
14	1	II	0.016	0.023	N	II	II	3223	Case rupture counter-clockwise 12 to 3 o'clock
14A	1	V	Not Fired Collapsed Cup						See Figure 24
14B	1	V	Not Fired Collapsed Cup						See Figure 24
14C	1	V	Not Fired Collapsed Cup						See Figure 24
15	1	II	0.0122	0.020	N	II	II	3119	Case rupture counter-clockwise 12 to 3 o'clock
16	1	II	0.010	0.030	N	N	II	3236	
17	1	II	0.009	0.033	N	I	II	3200	
17A	2	II	0.001	0.027	MSp	II	II	3190	
18	1	II	0.002	0.015	N	N	II	3166	
19	1	II	0.009	0.008	N	N	II	3183	
19A	1	V	Not Fired Collapsed Cup						See Figure 24
20	1	II	0.007	0.023	N	I	II	3212	
20A	1	V	Not Fired Collapsed Cup						See Figure 24
21	1	II	0.009	>0.066	N	N	V	3249	

Note:
1. Average weight of sealing cups 5.88 grains.
2. All cases showed sealing cup gas leak.
3. Final cup position and cup behavior during insertion and firing. (See Figures 23, 24, 25, 26, and 27.)
4. Type and location of erosion. See Figure 5.
5. Barrel replaced due to severe erosion.
6. Gap represents distance between cup base and web face.

TABLE VIII. Test Results of Sample P18[1,2]

Round	No. Cup Insertion Attempts	Cup Position After Insertion	FIE Gap (in.) After Insertion[5]	FIE Gap (in.) After Firing[5]	Breech Flash	Erosion Type[4]	Cup Behavior During Firing[3]	Velocity (fps)	Remarks
21A	1	V	Not Fired Collapsed Cup						See Figure 28
21B	3	II	0.011	0.032	N	I	II	3227	
21C	3	II	Not Fired Collapsed Cup						See Figure 28
21D	3	II	0.005	0.015	N	II	II	3240	
21E	3	II	0.003	0.023	–	I	II	3235	
21F	3	II	0.003	0.012	N	I	II	3203	
21G	1	II	0.003	0.013	SSp	II	II	3212	
21H	3	II	0.019	0.030	N	N	II	3238	
21I	3	II	0.005	0.011	SSp	II	II	3205	
21J	1	V	Not Fired Collapsed Cup						See Figure 28
21K	1	V	Not Fired Collapsed Cup						See Figure 28
22	1	II	0.004	0.017	SSp	II	II	3225	Blown primer cup base
22A	1	II	0.004	0.023	SSp	I	II	3202	
23	1	II	0.025	0.039	SSp	II	II	3174	
24	1	II	0.004	0.023	SSp	I	II	3214	
24A	3	II	0.007	0.028	SSp	I	II	3232	
25	1	II	0.009	0.027	N	I	II	3229	
25A	3	II	0.007	0.028	L	II	II	3229	
25B	3	II	0.009	0.030	SSp	I	II	3200	
26	1	II	0.035	0.027	N	I	II	3229	FIE particles adhered to extractor groove
27	1	II	0.133	0.045	N	–	II	3234	No induced failure groove
28	1	II	0.015	0.021	N	I	II	3204	See Figure 28
29	1	II	0.005	0.020	SSp	I	II	3199	See Figure 28
29A	1	V	Not Fired Collapsed Cup						See Figure 28
29B	1	V	Not Fired Collapsed Cup						See Figure 28
30	1	II	0.035	0.014	N	I	II	3203	
31	1	II	0.010	0.027	N	I	II	3191	
31A	1	V	Not Fired Collapsed Cup						See Figures 23 and 28
31B	1	II	0.013	0.027	N	I	II	3231	
32	1	II	0.005	0.027	SSp	I	II	3231	
33	1	II	0.006	0.029	SSp	I	II	3240	
33A	1	II	0	0.023	N	I	II	3231	Same as 26
33B	3	II	0.017	0.030	SSp	II	V	3245	

Note:
1. Average weight of cups 5.59 grains.
2. All rounds showed sealing cup gas leak except RD No. 27.
3. Final cup position and cup behavior during insertion and firing. (See Figures 23, 28, 29, 30, and 31.)
4. Type and location of erosion. See Figure 5.
5. Gap represents distance between cup base and web face.

TABLE IX. Test Results of Sample P19[1,2]

Round	No. Cup Insertion Attempts	Cup Position After Insertion	FIE Gap (in.) After Insertion[5]	FIE Gap (in.) After Firing[5]	Breech Flash	Muzzle Flash	Erosion Type[4]	Primer Behavior	Cup Behavior During Firing[3]	Velocity (fps)	Remarks
34	1	II	0.023	0.030	SSp	N	I	L		3269	
35	1	II	0.013	0.032	SSp	N	I	L		3250	Case rupture between 12 and 3 o'clock.
36	1	II	0.007	0.021	SSp	L	II	L		3209	Case rupture between 12 and 8 o'clock. Head face erosion.
36A	1	V	Not Fired Collapsed Cup								See Figure 32
37	1	II	0.012	0.037	N	L	I	L		3260	
38	1	II	0.014	0.032	SSp	SSp	I	PL		3244	
39	1	II	0.012	0.021	L	N	I	L		3262	Head face erosion, FIE particles in extractor groove.
39A	3	II	0.014	0.037	L	N	I	L		3245	Same as 39.
40	1	II	0.015	0.045	SSp	M	I	PL	All samples in II position	3255	FIE through induced failure area.
41	1	II	0.018	0.039	SSp	SSp	I	PL		3235	
42	1	II	0.012	0.033	SSp	SSp	I	L		3251	
43	1	II	0.010	0.026	SSp	L	II	PL		3231	FIE in extractor groove.
44	1	II	0.003	0.037	N	L	I	PL		3215	
44A	1	N	Not Fired Collapsed Cup								See Figure 32
45	1	II	0.019	0.023	N	SSp	I	L		3234	
46	1	II	0.009	0.027	N	L	I	PL		3243	
47	1	II	0.018	0.028	N	SSp	I	L		3214	
48	1	II	0.017	0.025	N	L	I	N		3211	
49	1	II	0.013	0.025	N	L	I	N		3207	
49A	3	II	0.012	0.023	SSp	L	I	N		3197	
50	1	II	0.014	0.020	N	L	I	L		3204	
51	1	II	0.010	0.021	N	L	I	PL		3179	
52	1	II	0.008	0.027	N	SSp	I	PL		3222	
53	1	II	0.009	0.023	N	L	I	PL		3203	
54	1	II	0.005	0.027	SSp	SSp	II	PL		3223	
55	1	II	0.003	0.028	N	SSp	I	PL		3270	
56	1	II	0.009	0.023	N	L	II	PL		3230	
57	1	II	0.008	0.022	SSp	SSp	I	L		3234	
58	1	II	0.006	0.030	MSp	SSp	I	PL		3225	
59	1	II	0.013	0.025	N	SSp	I	PL		3253	
60	1	II	0.013	0.040	N	SSp	I	PL		3227	
61	1	II	0.007	0.027	N	SSp	I	PL		3203	

Note:
1. Average weight of cups 5.74 grains.
2. All rounds showed sealing cup gas leaks.
3. Final cup position and cup behavior during insertion and firing. (See Figures 23, 32, 33, 34, and 35.)
4. Type and location of erosion. See Figure 5.
5. Gap represents distance between cup base and web face.

TABLE X. Test Results of Sample P20[1,2]

Round	No. Cup Insertion Attempts	Cup Position After Insertion	FIE Gap (in.) After Insertion[5]	FIE Gap (in.) After Firing[5]	Breech Flash	Erosion Type[4]	Cup Behavior During Firing[3]	Velocity (fps)	Remarks
62	1	II	0.002	0.025	M	II	II	3197	
63	1	II	0.002	0.019	N	I	II	3231	FIE particles in extractor groove
63A	2	II	0.005	0.027	N	I	II	3204	FIE in extractor groove, case split at induced area, 12 to 11 o'clock.
63C	2	II	0.010	0.030	N	I	V	3246	
63D	2	II	0.0	0.013	N	I	II	3220	
63E	2	II	Not Fired Collapsed Cup						See Figure 36
63F	1	II	0.010	0.023	SSp	I	II	3210	FIE in extractor groove
64	1	II	0.001	0.013	SSp	II	II	3211	FIE in extractor groove
65	1	II	0.008	0.021	SSp	I	II	3220	
66	1	II	0.007	0.025	N	I	II	3222	FIE in extractor groove
66A	1	V	Not Fired Collapsed Cup						See Figure 36
66B	1	V	Not Fired Collapsed Cup						See Figure 36
66C	1	V	Not Fired Collapsed Cup						See Figure 36
66D	2	II	0.011	0.020	N	N	II	3240	
67	1	II	0.013	0.037	SSp	I	II	3240	
68	1	II	0.016	0.028	SSp	I	II	3189	FIE in extractor groove
69	1	II	0.001	0.030	SSp	I	II	3206	
69A	1	V	Not Fired Collapsed Cup						See Figure 36
70	1	II	0.015	0.028	SSp	I	II	3276	
70A	1	V	Not Fired Collapsed Cup						See Figure 36
71	1	II	0.003	0.025	SSp	II	II	3226	
72	1	II	0.027	0.037	N	I	II	3205	
73	1	II	0.008	0.027	N	I	II	3228	FIE in extractor groove
74	1	II	0.029	0.060	N	I	V	3226	
75	1	II	0.029	0.019	SSp	I	II	3230	
76	1	II	0.013	0.039	SSp	II	II	3233	
77	1	II	0.001	0.028	N	I	II	3221	
77A	2	II	0.002	0.027	SSp	II	II	3219	
78	1	II	0.003	0.021	SSp	II	II	3237	
79	1	II	0.003	0.021	SSp	I	II	3234	
80	1	II	0.017	0.021	MSp	III	II	3204	
80A	2	II	0.010	0.021	N	I	II	3225	FIE in extractor groove
81	1	II	0.002	0.032	N	I	II	3232	

Note:
1. Average weight of cups 5.52 grains.
2. All rounds showed sealing cup gas leaks.
3. Final cup position and cup behavior during insertion and firing. (See Figures 23, 36, 37, 38, and 39.)
4. Type and location of erosion. See Figure 5.
5. Gap represents distance between cup base and web face.

TABLE XI. Test Results of Sample P21[1,2]

Round	No. Cup Insertion Attempts	Cup Position After Insertion	FIE Gap (in.) After Insertion[5]	FIE Gap (in.) After Firing[5]	Breech Flash	Erosion Type[4]	Cup Behavior During Firing[3]	Velocity (fps)	Remarks
82	1	II	0.004	0.027	N	I	All samples in II position.	3225	FIE in extractor groove.
82A	2	II	0.011	0.029	N	II		3235	
82B	1	V	Not Fired	Collapsed	Cup				See Figure 40
83	1	II	0.002	0.023	N	I		3234	
84	1	II	0.003	0.027	SSp	I		3238	
85	1	II	0.012	0.029	SSp	II		3218	
86	1	II	0.014	0.027	SSp	I		3227	
87	1	II	0.005	0.023	MSp	I		3206	
87A	2	II	0.003	0.021	MSp	I		3234	
88	1	II	0.011	0.037	MSp	I		3221	
89	1	II	0.005	0.028	SSp	I		3214	
90	1	II	0.007	0.023	SSp	I		3209	
91	1	II	0.009	0.028	SSp	I		3233	
92	1	II	0.010	0.032	MSp	II		3242	
93	1	II	0.002	0.029	–	I		3234	
94	1	II	0.014	0.033	N	I		3229	
95	1	II	0.006	0.040	N	I		3226	Mouth split.
95A	1	V	Not Fired	Collapsed	Cup				See Figure 40
96	1	II	0.012	0.028	SSp	I		3245	
97	1	II	0.009	0.025	SSp	II		3193	
98	1	II	0.007	0.020	N	I		3218	
99	1	II	0.035	0.050	N	I		3187	Case split 2 to 9 o'clock
100	1	II	0.009	0.023	SSp	I		3226	
101	1	II	0.015	0.037	N	I		3235	FIE in extractor groove
102	1	II	0.012	0.030	SSp	I		3216	Case split 12 to 1 o'clock
103	1	II	0.013	0.029	SSp	I		3201	Case split 12 to 9 o'clock (counter-clockwise)
104	1	II	0.014	0.033	M	II		3208	
105	1	II	0.005	0.031	SSp	I		3236	
106	1	II	0.009	0.031	N	I		3229	
106A	2	II	0.007	0.027	N	I		3197	

Note:
1. Average weight of cups 5.73 grains.
2. All rounds showed sealing cup gas leaks.
3. Final cup position and cup behavior during insertion and firing. (See Figures 23, 40, 41, 42, and 43.)
4. Type and location of erosion. See Figure 5.
5. Gap represents distance between cup base and web face.

Photographs (x-ray) of sealing cups inserted into cases, assembled cartridge cases, cases after fire, and exterior view of fired cases are shown in Figures 24 to 43. The results of this series of test firings are summarized in Table XII.

Legend of Test Firing Observations

Breech Flash	Erosion Type
N - None	N - None
S - Small	See Figure 5 for other codes
M - Medium	
VL - Very large	
Sp - Sparks	

The following observations were made during and after the test:

1. The cups did not have the capability to return to their original shape after being folded.

2. Most sealing cups were damaged during insertion.

3. Lubrication was required to sealing cups during insertion, and many cups could not be seated flush against the surface of the web.

It was concluded that the compositions required revision in order that the cups will have the capability to return to their original shape after being folded.

Third Test Series

A series of formulations was prepared to give the cups the capability to return to their original shape after being folded (Table XIII). The approaches included (using Formulation PIO as a base):

1. Use of higher molecular weight polymer

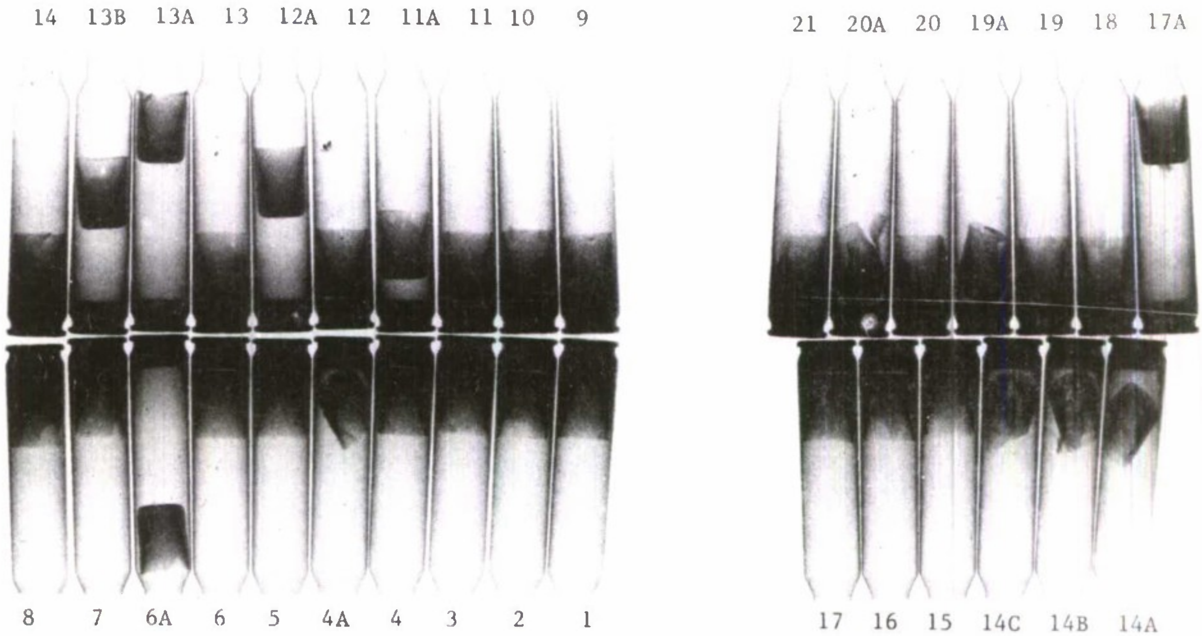
2. Use of a more highly crosslinked polymer

3. Use of a plasticizer

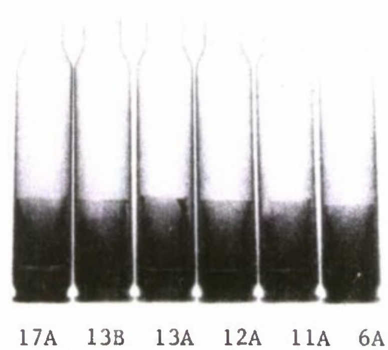
4. Variation of the amount of the filler, Thermax

5. Use of a terpolymer polysulfide binder

A new feature of this test series was the reduction in length of the cups from 13/32 inches to 5/16 inches (Figure 3). This change would present a strengthened upper portion of the cup and reduce the volume of the cup. This change appeared to be feasible as long as the cup length was greater than the diameter of the case.



Initial FIE Position



Final FIE Position

Figure 24. X-Ray View of Lot P10 After FIE Insertion

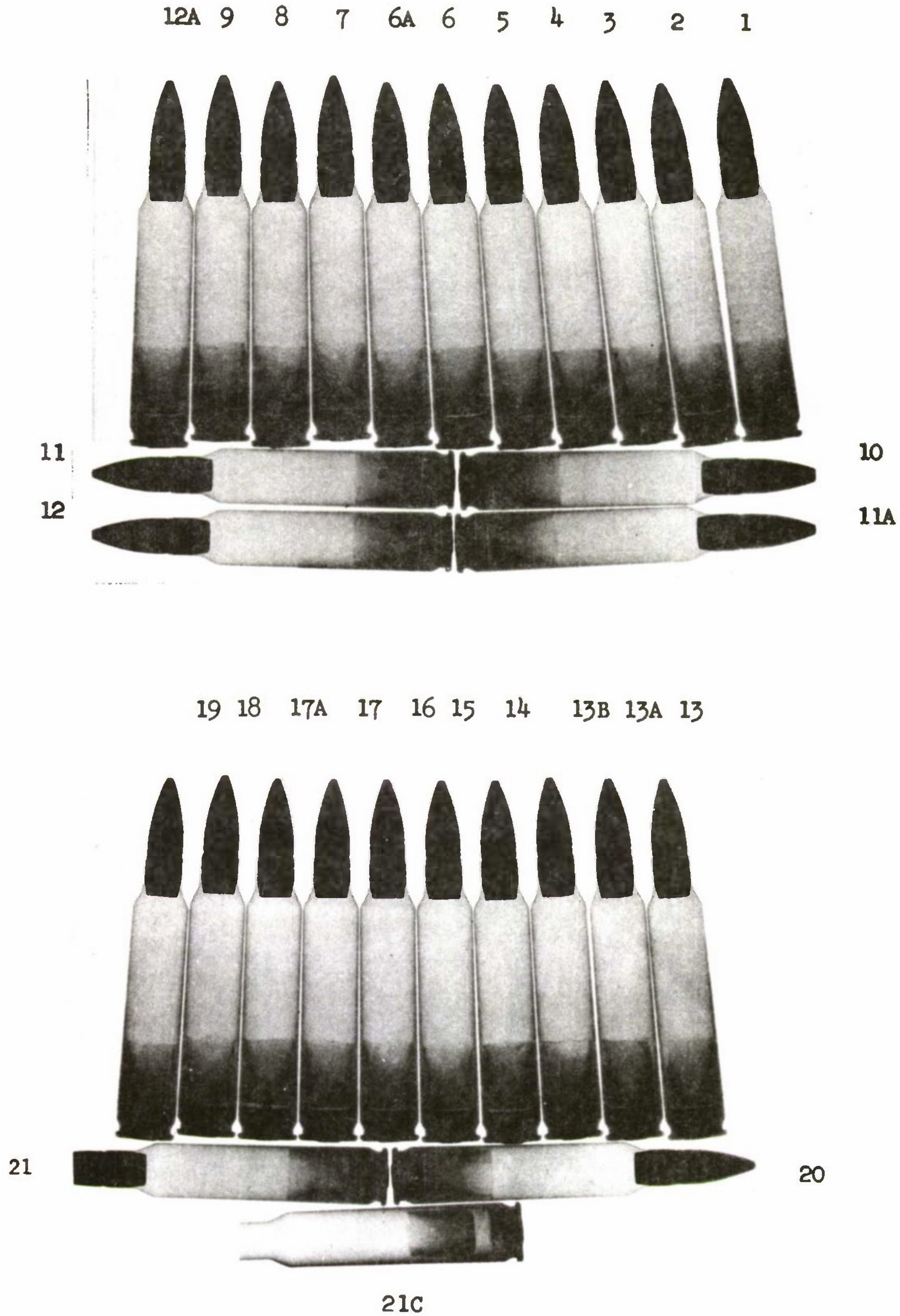


Figure 25. X-Ray View of Cartridge Assembly Lot P10 Before Fire

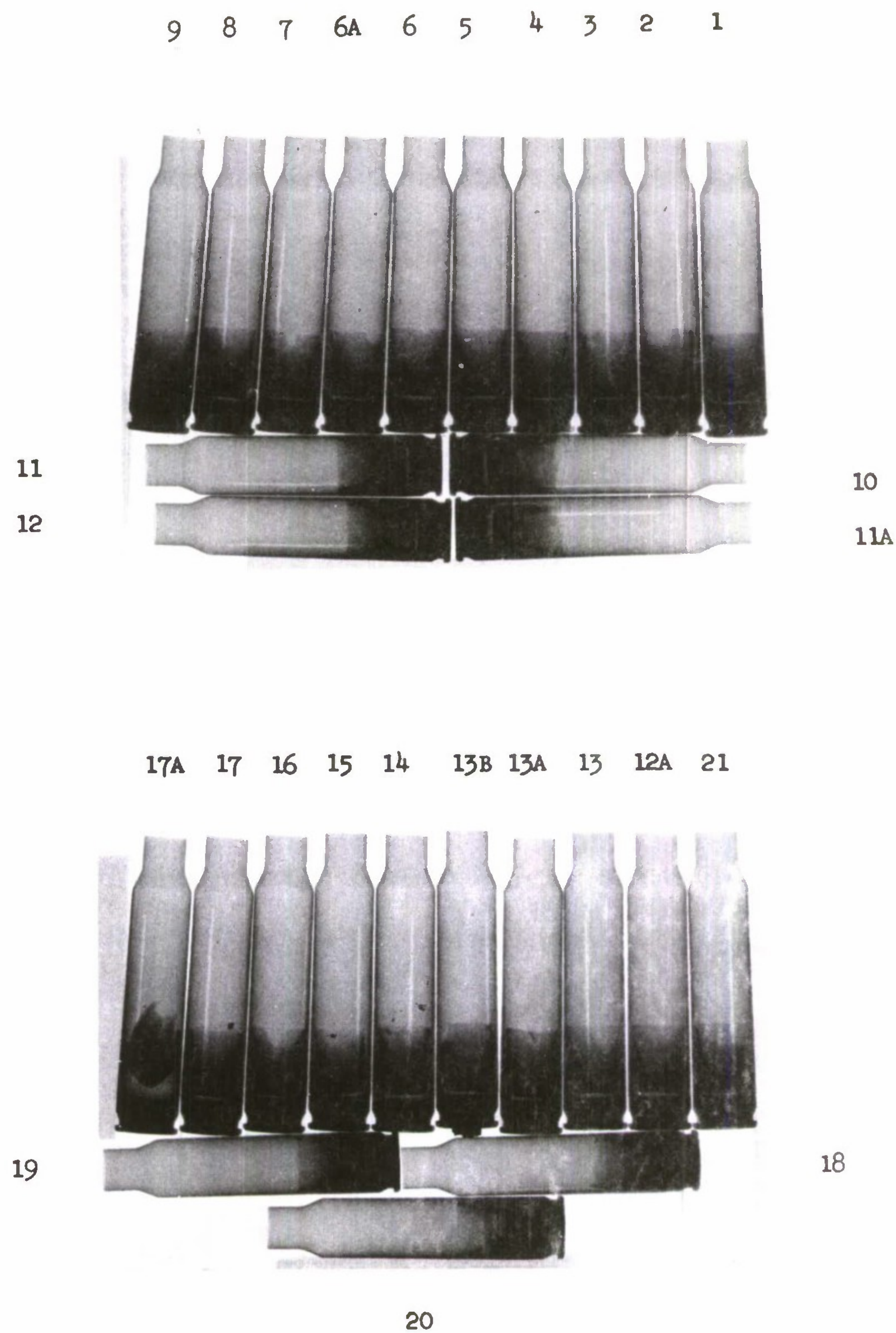
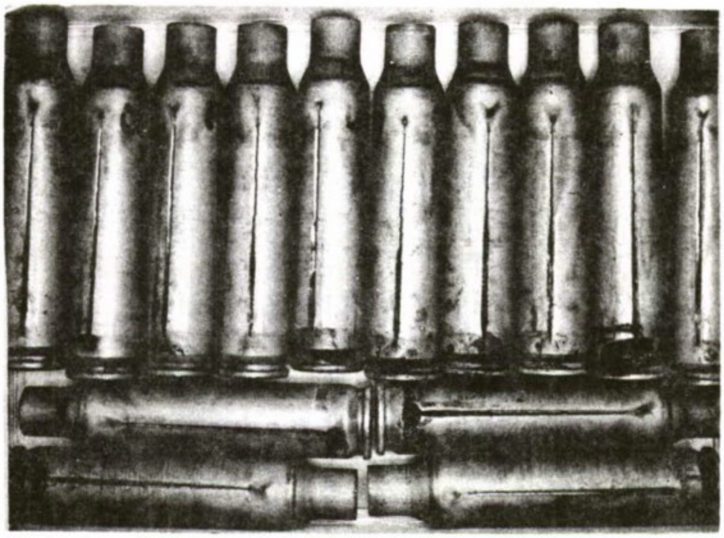


Figure 26. X-Ray View of Lot P10 After Fire



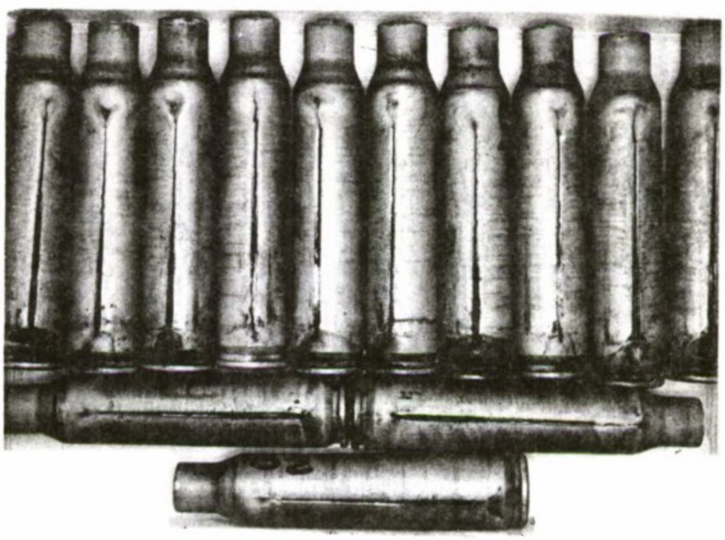
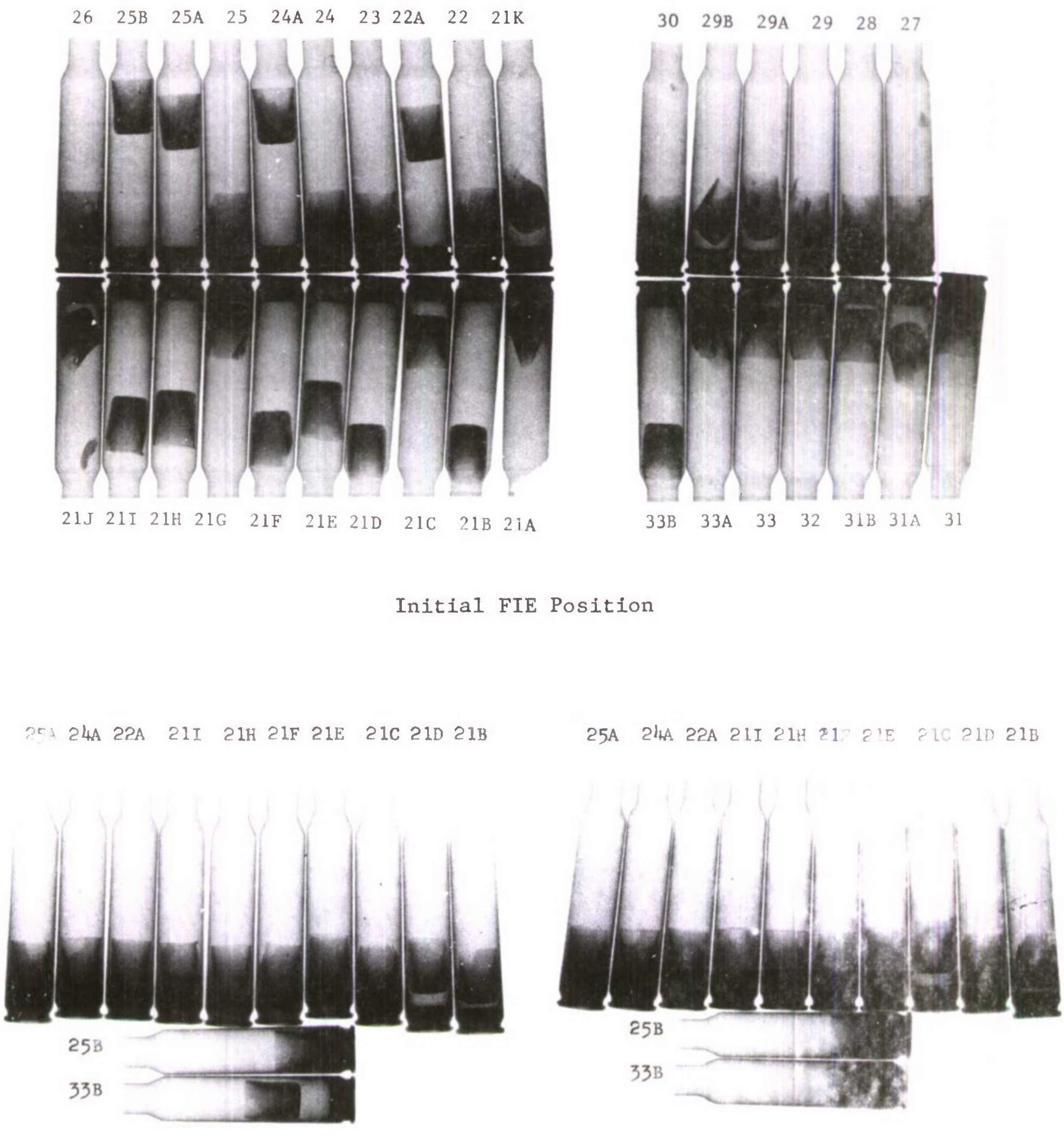


Figure 27. External View of Lot P10 After Fire



Initial FIE Position

Second FIE Position

Final FIE Position

Figure 28. X-Ray View of Lot P18 After FIE Insertion

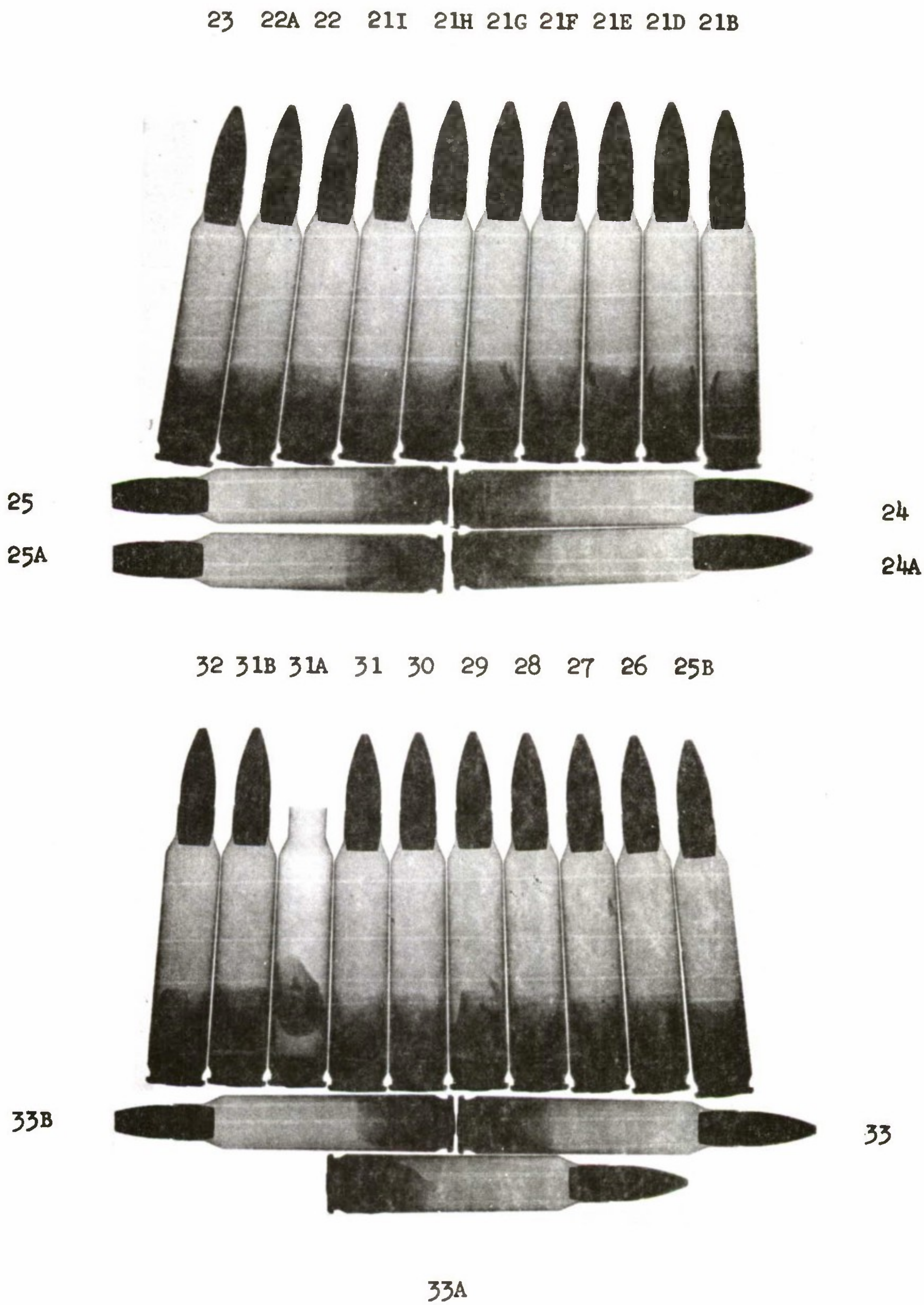


Figure 29. X-Ray View of Cartridge Assembly Lot P18 Before Fire

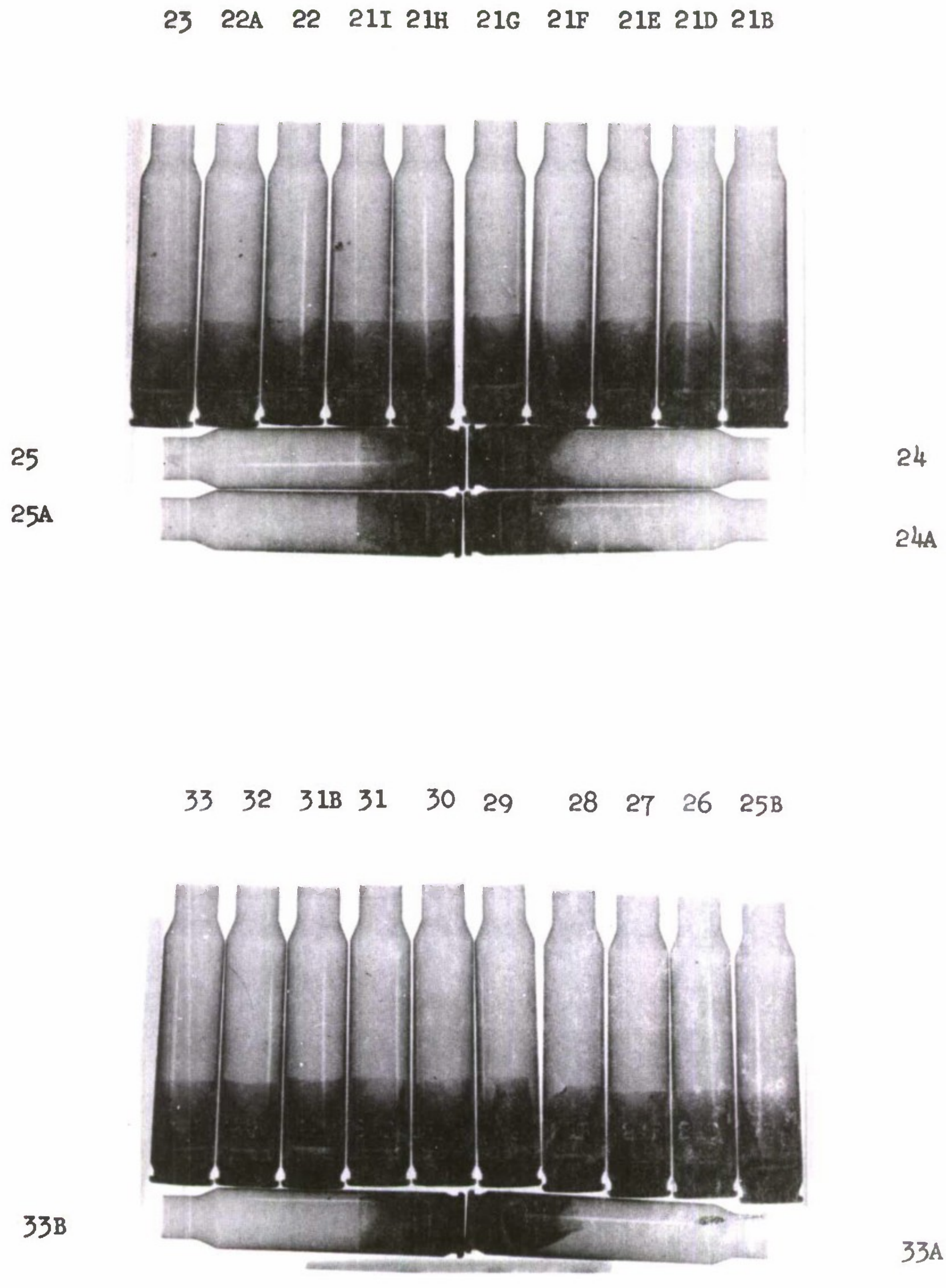
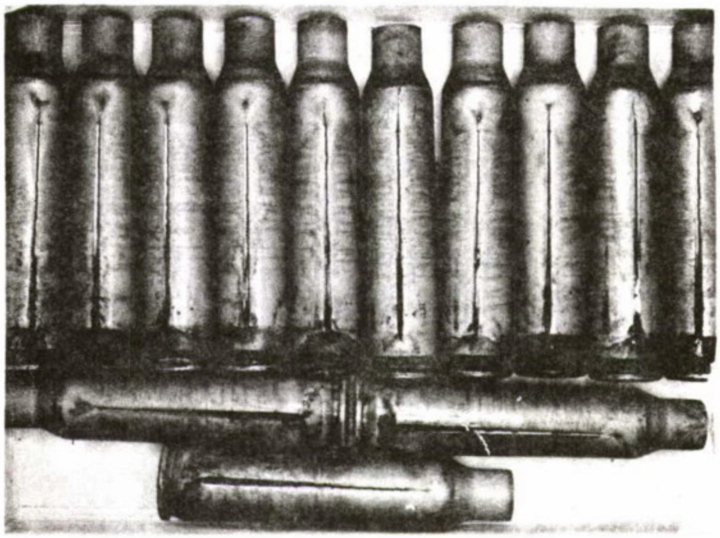


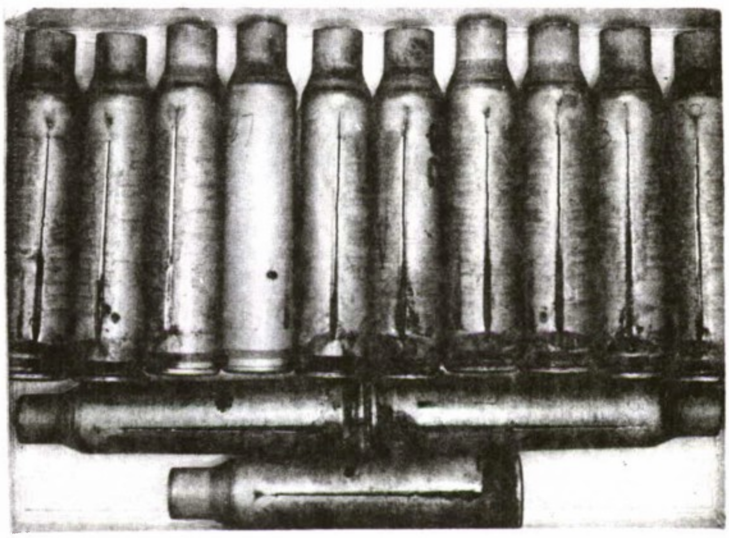
Figure 30. X-Ray View of Lot P18 After Fire

21B 21D 21E 21F 21G 21H 21I 22 22A 23

24  24A

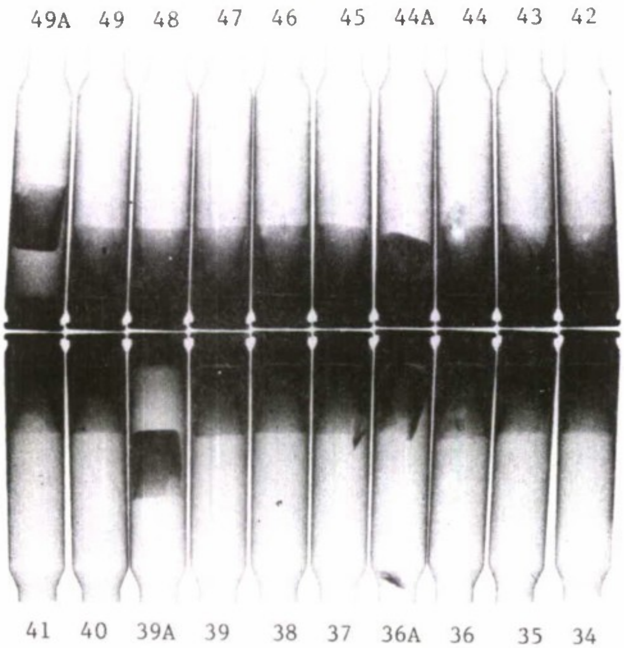
25

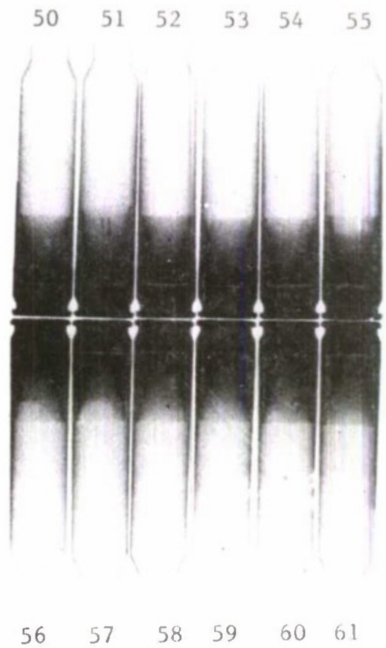
25A 25B 26 27 28 29 30 31 31B 32

33  33A

33B

Figure 31. External View of Lot P18 After Fire





Second FIE Position

Final FIE Position

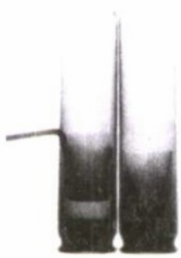


Figure 32. X-Ray View of Lot P19 After FIE Insertion

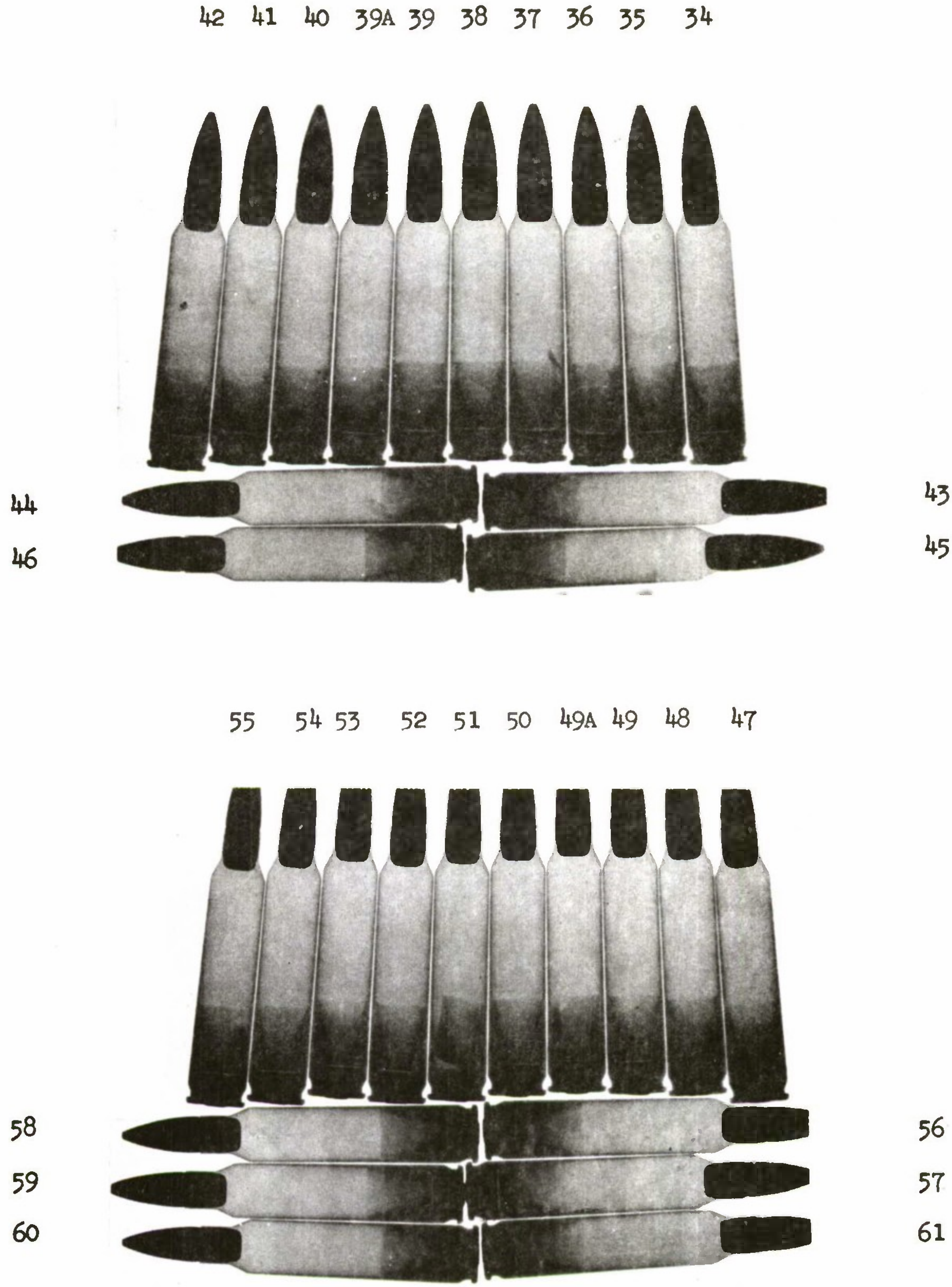


Figure 33. X-Ray View of Cartridge Assembly Lot P19 Before Fire

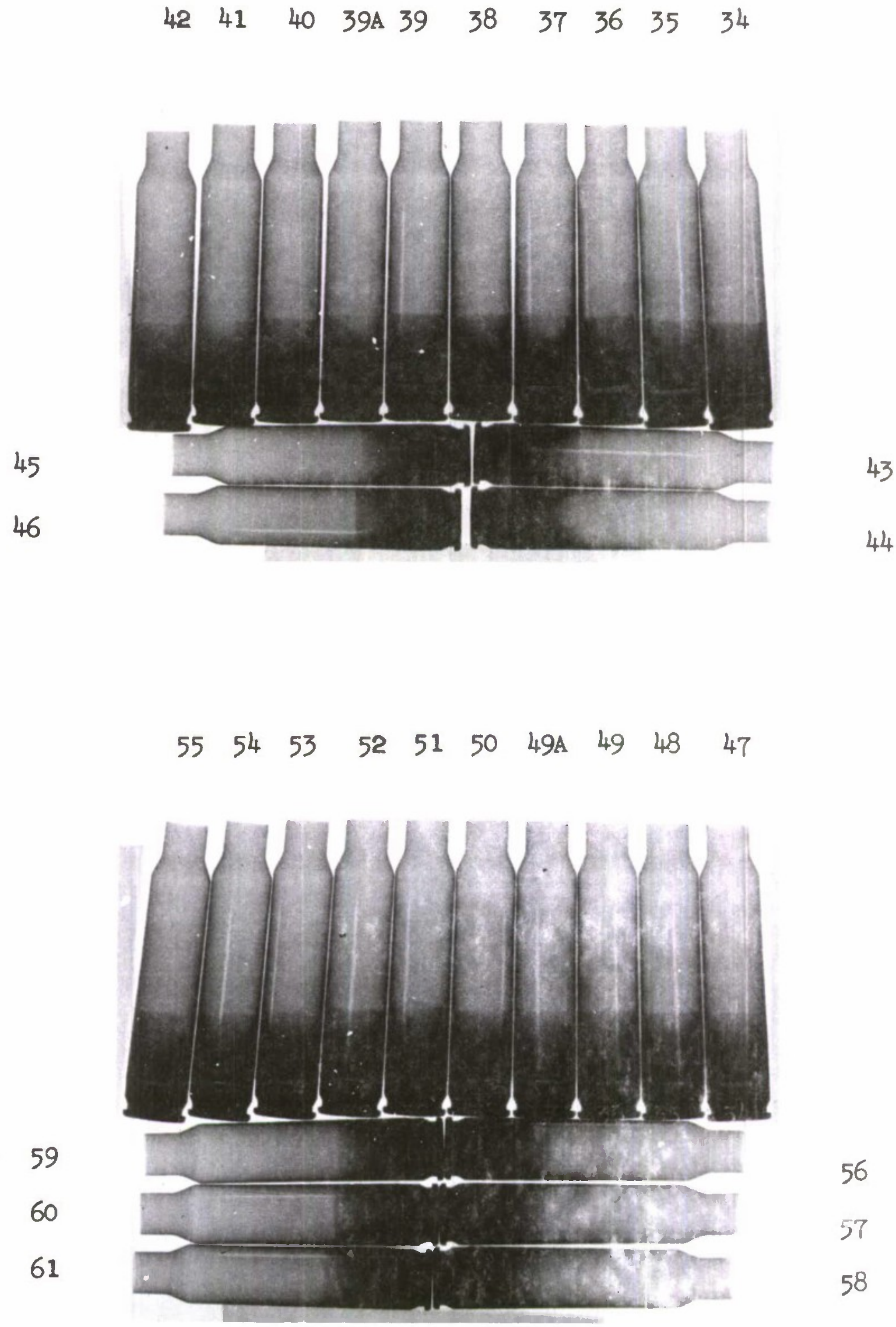


Figure 34. X-Ray View of Lot P19 After Fire

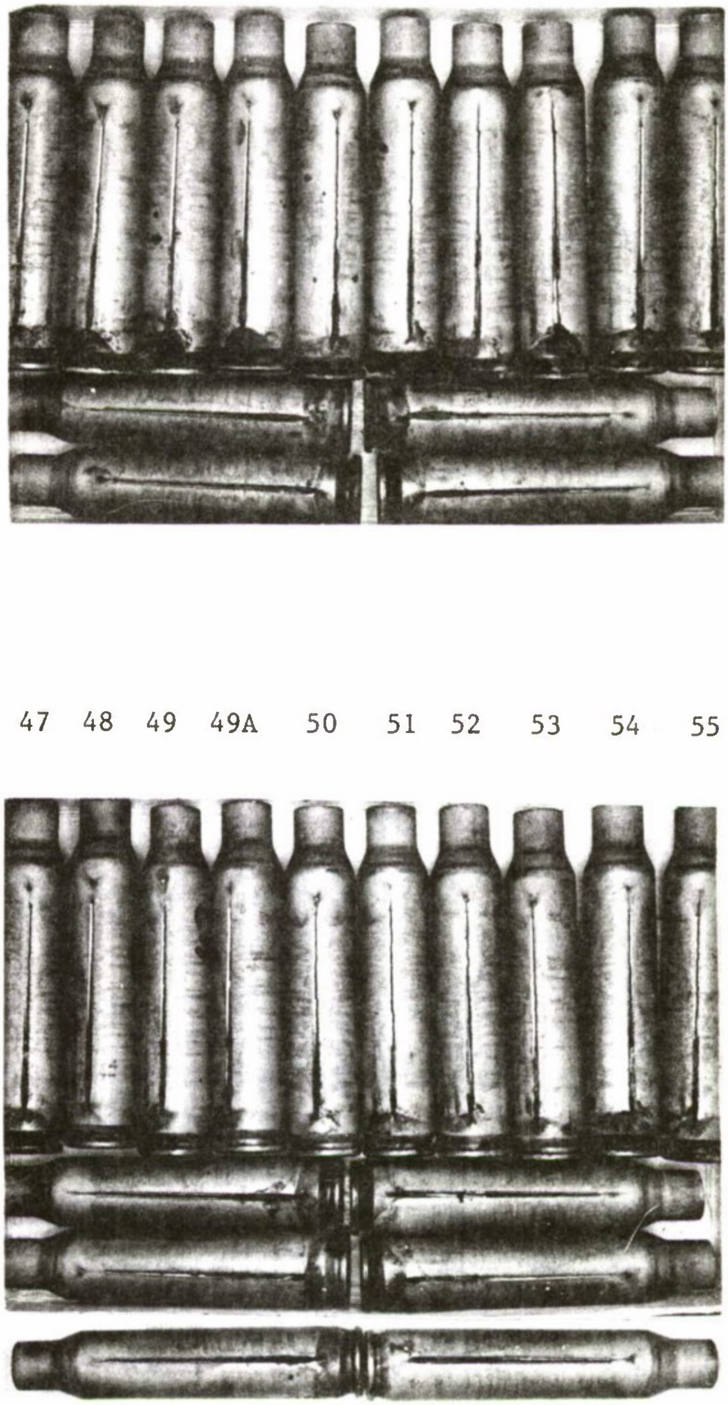
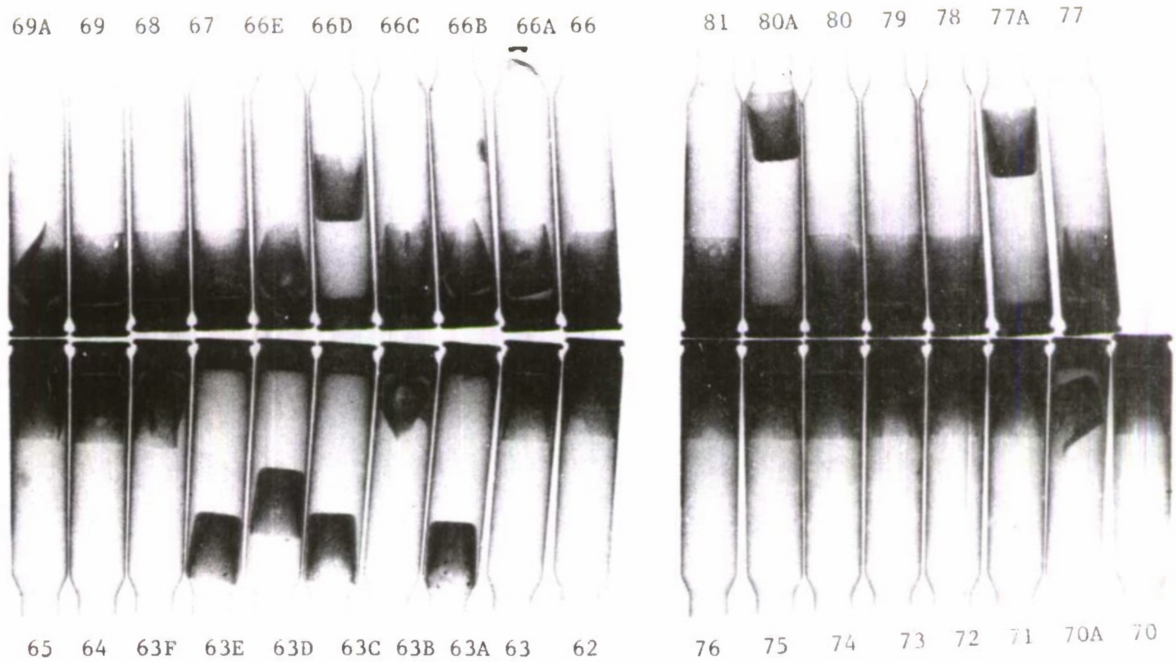
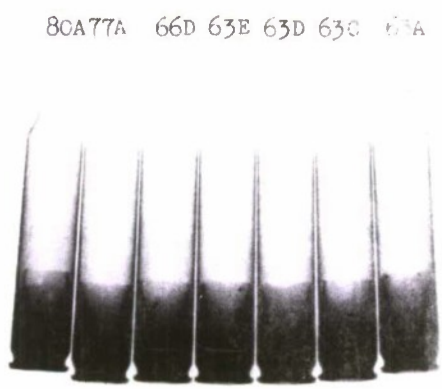


Figure 35. External View of Lot P19 After Fire



Initial FIE Position



Second FIE Position

Figure 36. X-Ray View of Lot P20 After FIE Insertion

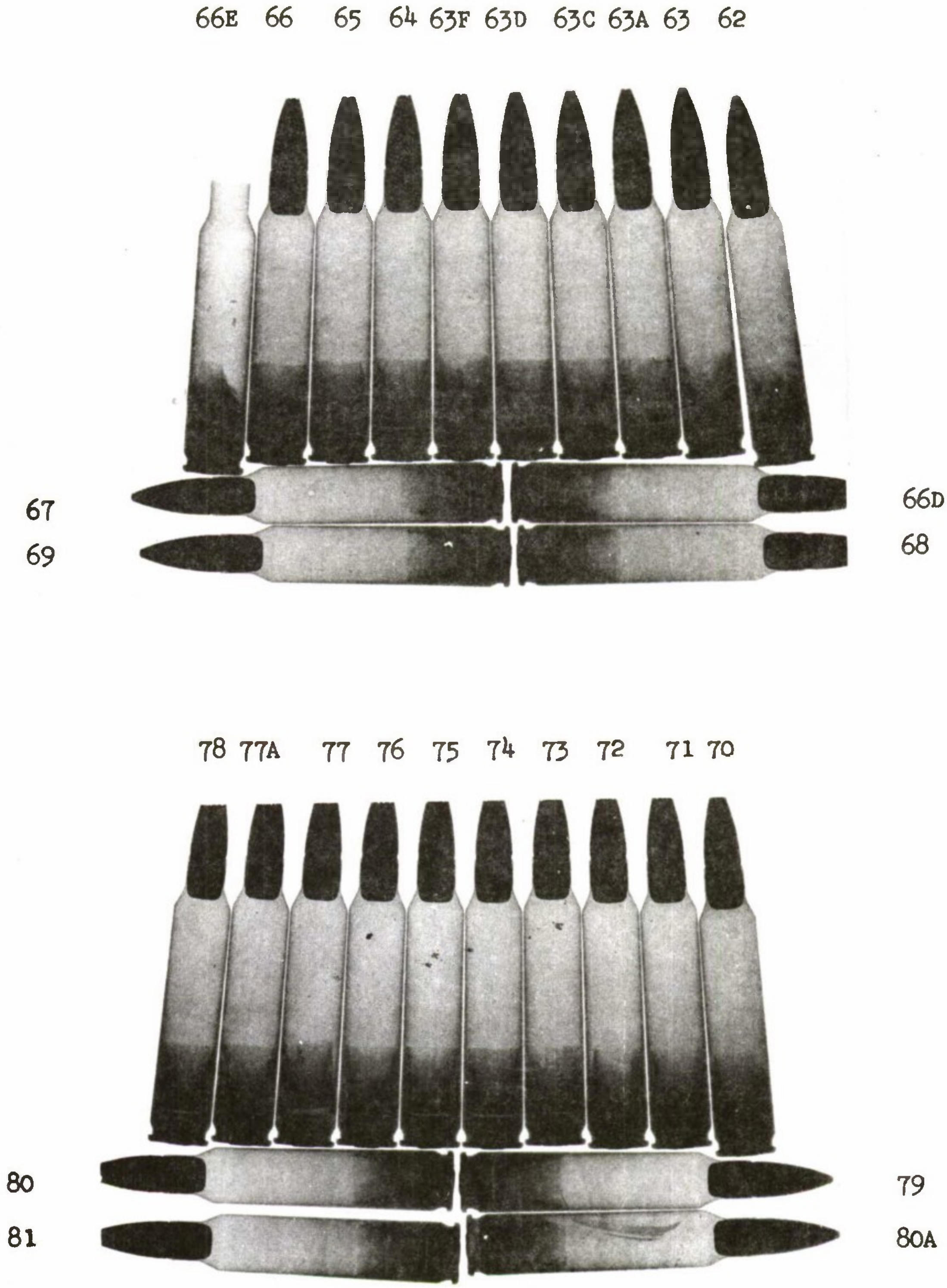


Figure 37. X-Ray View of Cartridge Assembly Lot P20 Before Fire

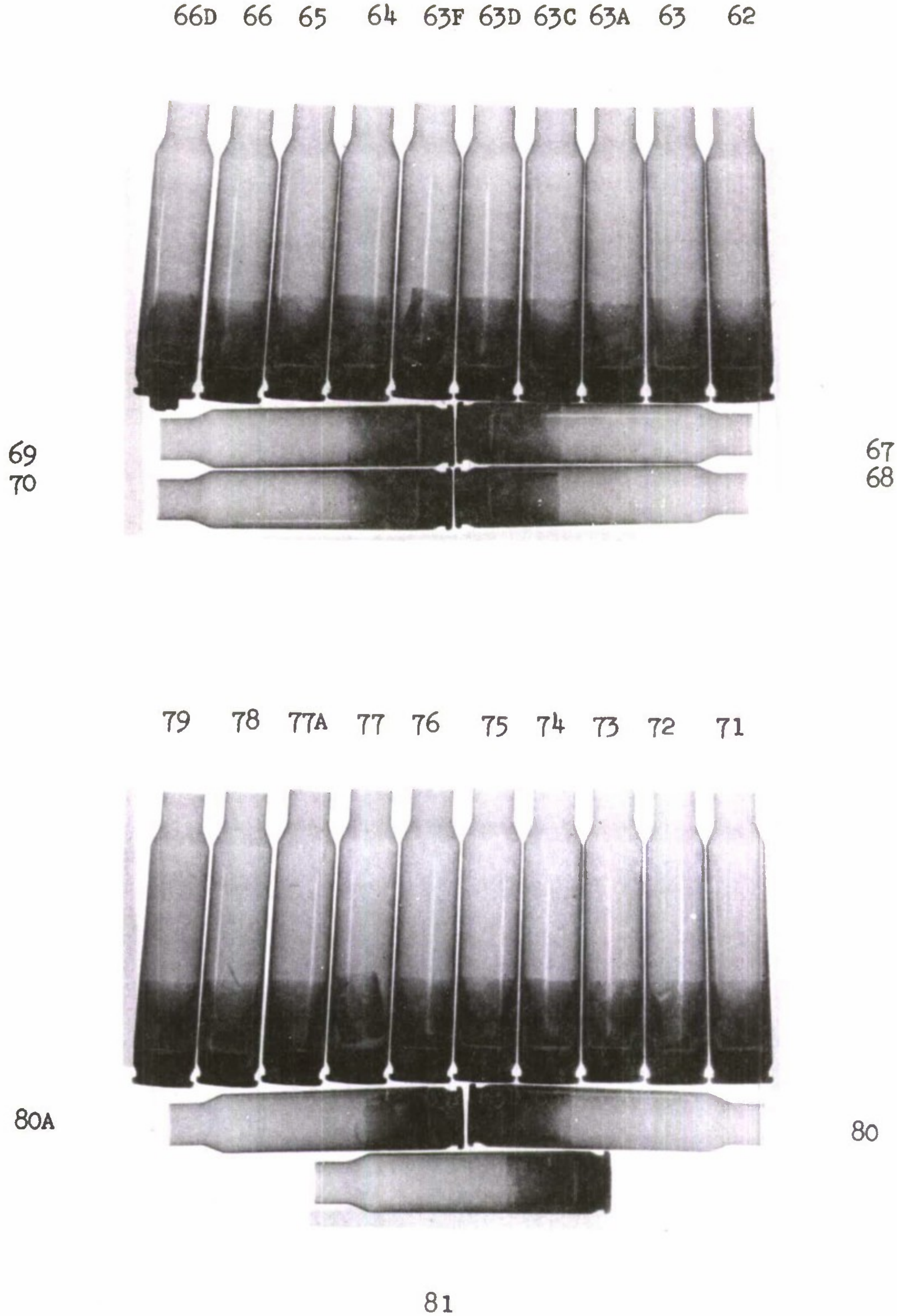
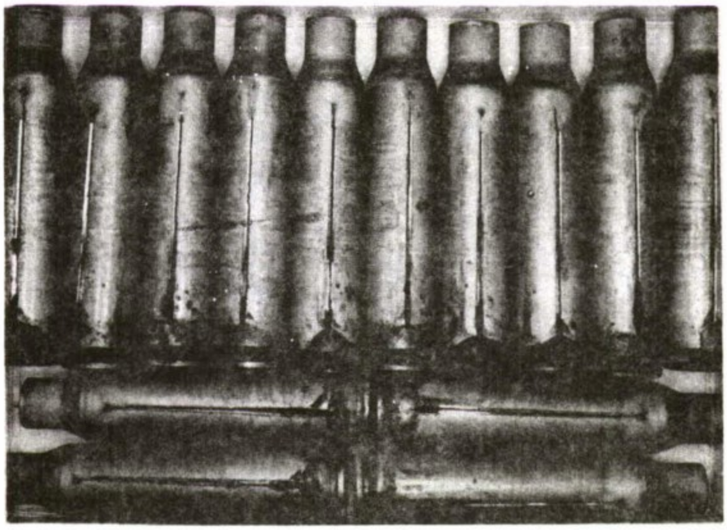


Figure 38. X-Ray View of Lot P20 After Fire

62 63 63A 63C 63D 63F 64 65 66 66D

67 68

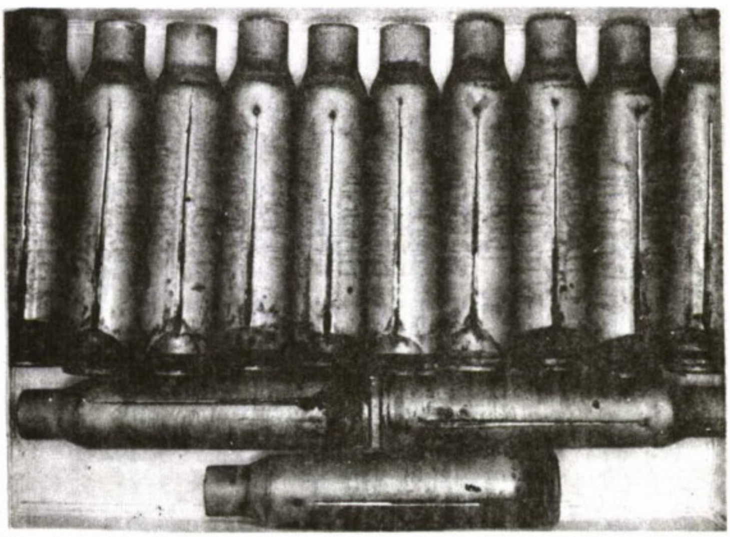
69 70



71 72 73 74 75 76 77 77A 78 79

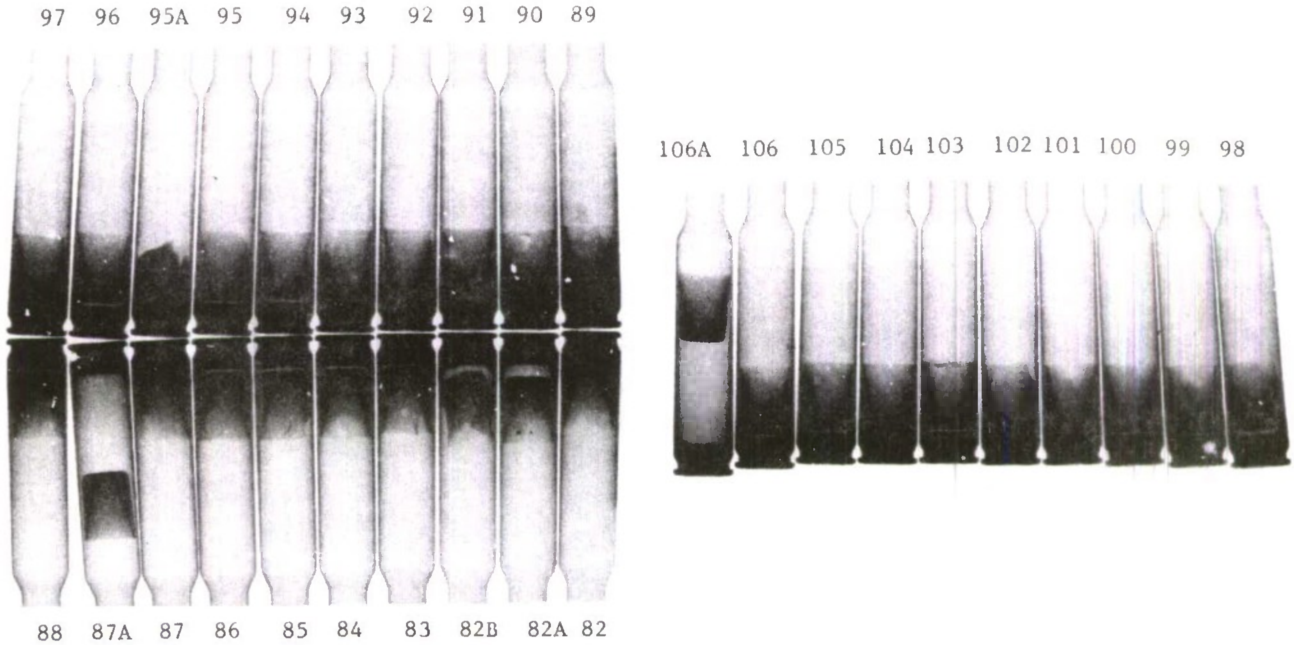
80A

80

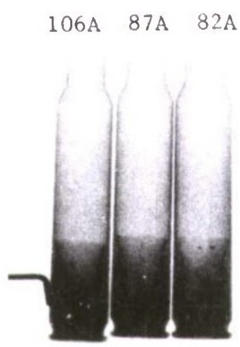


81

Figure 39. External View of Lot P20 After Fire



Initial FIE Position



Final FIE Position

Figure 40. X-Ray View of Lot P21 After FIE Insertion

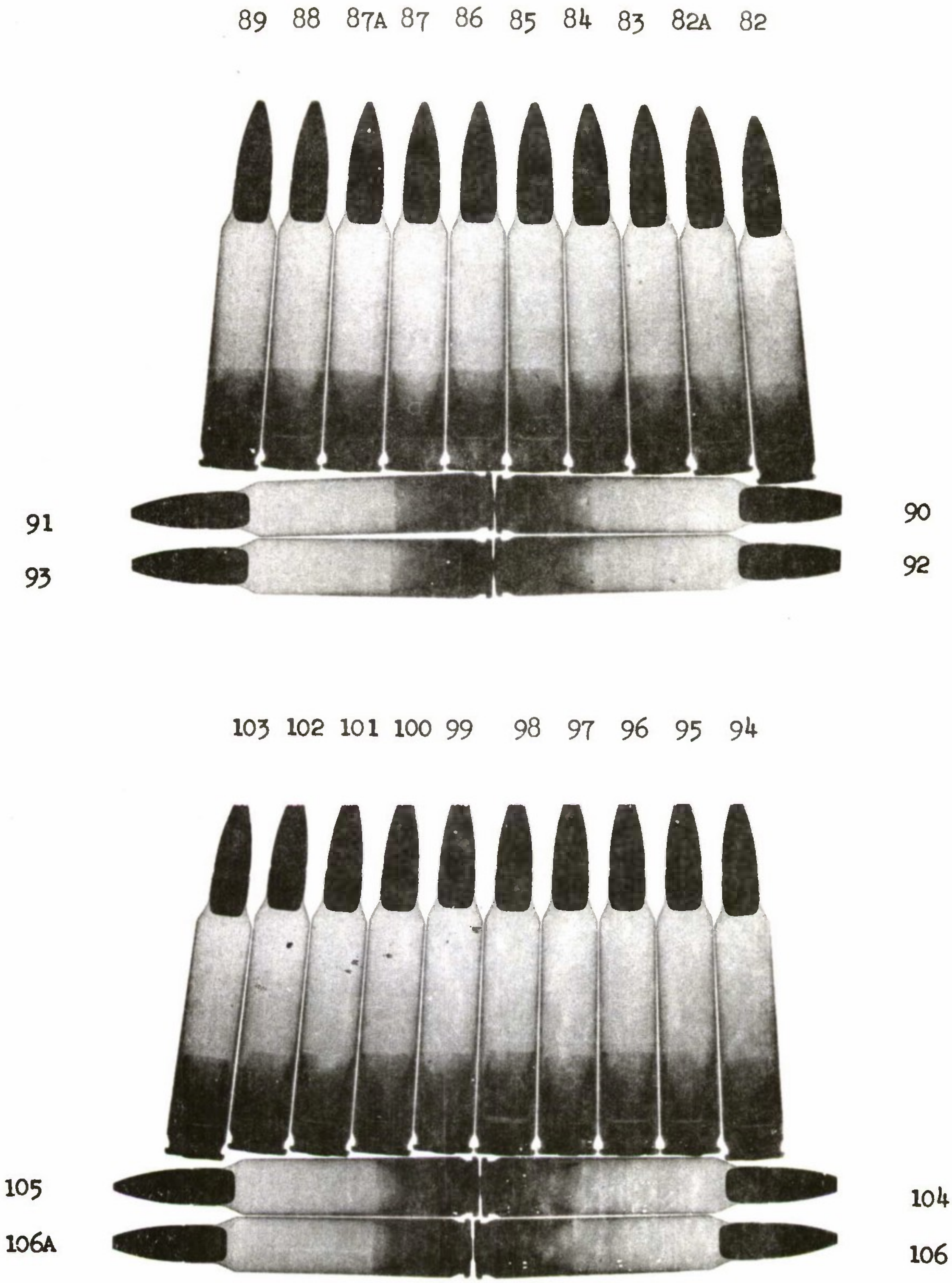


Figure 41. X-Ray View of Cartridge Assembly Lot P21 Before Fire

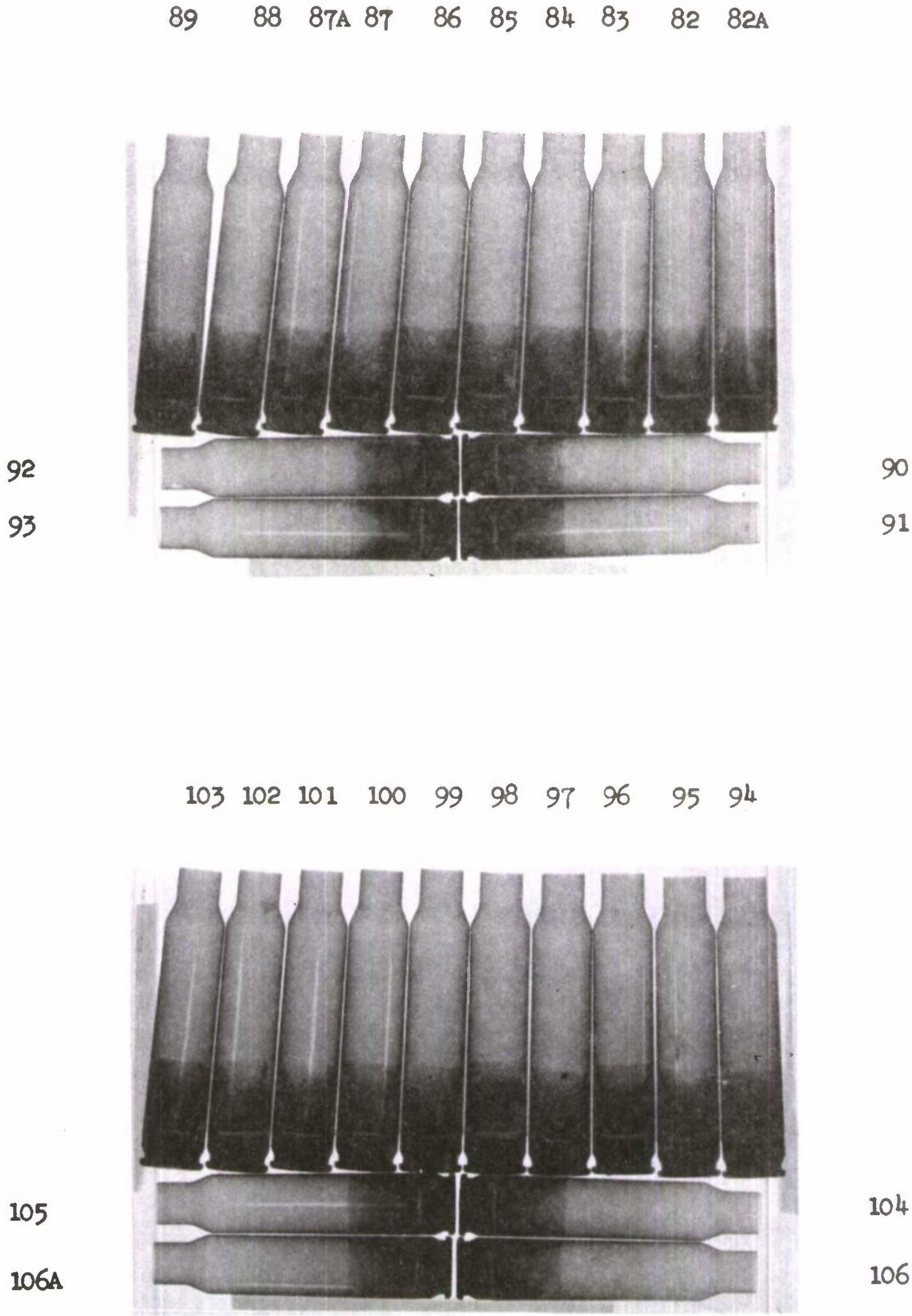


Figure 42. X-Ray View of Lot P21 After Fire

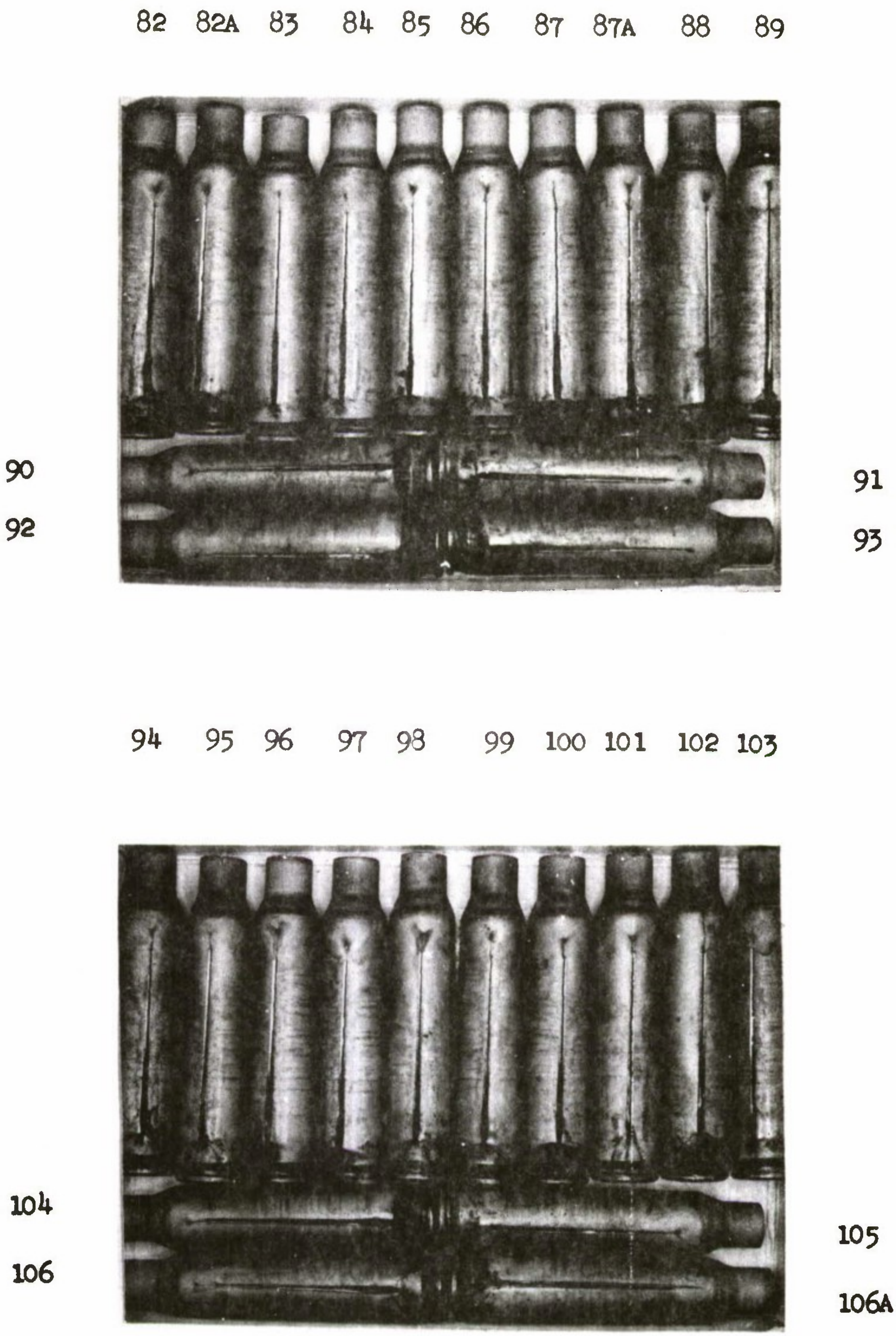


Figure 43. External View of Lot P21 After Fire

TABLE XII.
Summary of Second Test Firings

Formulation	Identification	Remarks and Results
P10	20% Thermax	48% Case Erosion (Type I and II) and 15% Breech Flashes.
P18	10% Thermax	52% Case Erosion (Type I and II) and 96% Breech Flashes.
P19	3.6% LP205 and 3.3% LP370	100% Case Erosion (Type I and II) and 47% Breech Flashes.
P20	4.1% LP 205 and 3.7% LP 370	100% Case Erosion (Type I, II, and III) and 92% Breech Flashes.
P21	15% Thermax	100% Case Erosion (Type I and II) and 59% Breech Flashes.

Note: Most cups were damaged during insertion; could not be seated against web surface, and did not have the capability to return to their original shape after being folded.

TABLE XIII.
Polysulfide Formulations (Third Test Series)

Formulation	P22	P23	P24	P25
LP-31	72.0	-	-	-
C5500 Paste	8.0	10.5	15.0	10.5
Thermax	20.0	18.8	25.0	20.0
TP90B	-	10.0	-	10.0
LP-32	-	60.7	-	-
LP-2	-	-	60.0	59.5

Formulation	P26	P27	P28	P29
LP-2	59.5	63.8	58.3	55.2
C5500 Paste	10.5	11.0	10.3	14.5
Thermax	25.0	20.0	29.4	25.0
LP-205	-	-	-	2.7
SP-370	-	-	-	2.6
TP90B	5.0	5.0	5.0	2.0

Physical properties of the two most promising candidates are:

Formulation	P23	P27
Shore A Hardness	30	38
Stress, psi	138	147
Elongation, %	322	312
Tear, pli (die c)	45	42
Density, g/cm^3	1.41	1.33

Results of the firings are presented in detail in Tables XIV to XXII. The test date was 10 July 1974. Test conditions were the same as for the second test series except that the cups were 5/16 inch in length.

Photographs (x-ray) of sealing cups inserted into cases, cases fired and exterior view of fired cases are shown in Figures 44 to 52.

Legend of Test Firing Observations

Breech Flash

N - None
S - Small
M - Medium
L - Large
VL - Very large
Sp - Sparks

Erosion Type

N - None
See Figure 5 for other codes.

The results of this series of test firings are summarized in Table XXIII. Several formulations showed excellent behavior, but Sample P27 showed the best results and was recommended for further testing. The tests also showed that the use of the 5/16-inch-long cup vs 13/32 inch is feasible. It was noted that reducing the length of the cup for the P10 formulation did not sufficiently improve it to make it competitive. Formulation P28, the 29.4-percent level of the Thermax filler resulted in too great a stiffening and this caused difficulty in insertion with consequent poor firing behavior, possibly because of damage incurred during insertion. The cost breakdown of Sample P27 is shown in Table XXIV.

TABLE XIV.
Teat Reaulta of Formulation P10[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
1	II	0.013	0.024	SSp	II	S	3239	
2	II	0.009	0.021	L	I8	M	3235	Head face erosion.
3	III	0.013	0.024	L	I	M	3249	Head face erosion.
4	II	0.007	0.024	L	IB	L	3189	
5	II	0.013	0.025	N	IB	M	3219	Head face eroaion.
6	II	0.007	0.015	SSp	I	M	3249	
7	II	0.009	0.024	N	I	S	3229	
9	II	0.007	0.019	N	N	S	3208	
10	II	0.014	0.020	N	N	S	3240	
11	II	0.016	0.020	MSp	IIB	M	3222	
12	II	0.008	0.059	L	III	L	3178	
13	II	0.013	0.023	SSp	II	M	3234	
14	II	0.016	0.019	MSp	I	S	3227	

Note: 1. Average weight of aealing cups 5.191 grains.
2. Cup position after insertion and firing. See Figurea 23 and 44.
3. Type and location of eroaion. See Figure 5.
4. Gap represents diatsnce between cup baae and web face.

TABLE XV.
Test Results of Formulation P22[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
15	II	0.012	0.020	N	I	M	3120	
16	II	0.014	0.025	N	N	S	3182	
17	II	0.013	0.023	N	I	M	3207	

Note: 1. Average weight of sealing cups 4.767 grains.
2. Cup position after insertion and firing. See Figures 23 and 45.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup and web face.

TABLE XVI.
Test Results of Formulation P23[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
18	II	0.023	0.027	N	N	S	3174	
19	II	0.024	0.026	N	I	S	3195	
20	II	0.022	0.028	N	I	S	3223	
21	II	0.007	0.013	N	N	S	3201	
22	II	0.017	0.020	N	I	S	3204	
23	II	0.013	0.023	N	I	S	3172	

Note: 1. Average weight of sealing cups 4.967 grains.
2. Cup position after insertion and firing. See Figures 23 and 46.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup and web face.

TABLE XVII.
Test Results of Formulation P24[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
24	II	0.012	0.020	N	I	S	3182	
25	II	0.011	0.021	N	I	S	3190	
26	II	0.013	0.016	N	I	S	3173	
27	II	0.014		VL	III	N	3098	Cup blown out of cartridge.

Note: 1. Average weight of sealing cups 5.290 grains.
2. Cup position after insertion and firing. See Figures 23 and 47.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup and web face.

TABLE XVIII.
Test Results of Formulation P25[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
29	II	0.015	0.017	N	N	S	3191	
30	V	Not Fired Collapsed Cup						See Figure 48.
31	II	0.003	0.013	N	N	S	3202	
32	II	0.007	0.019	N	I	S	3185	
33	II	0.009	0.025	N	I	S	3188	
34	II	0.001	0.020	N	I	S	3208	
35	II	0.001	0.013	N	I	S	3238	
36	II	0.005	0.021	SSp	II	L	3181	
37	II	0.001	0.013	N	N	S	3193	
38	II	0.002	0.016	N	I	S	3191	

Note: 1. Average weight of sealing cups 4.478 grains.
2. Cup position after insertion and firing. See Figures 23 and 48.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup and web face.

TABLE XIX.
Test Results of Formulation P26[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
39	II	0.003	0.013	N	N	S	3207	
40	II	0.003	0.019	N	I	M	3214	
41	V	Not Fired Collapsed Cup						See Figure 49.
42	II	0.001	0.017	N	I	S	3205	
43	II	0.002	0.019	N	I	S	3214	
44	III	Not Fired Collapsed Cup						See Figure 49.
45	II	0.002	0.014	N	N	S	3212	See Note 5.
46	II	0.010	0.026	MSp	II	M	3195	

Note: 1. Average weight of sealing cups 5.125 grains.
2. Cup position after insertion and firing. See Figures 23 and 49.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup and web face.
5. Some protrusion of cup through induced area.

TABLE XX.
Test Results of Formulation P27[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) Before Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
47	V	Not Fired Collapsed Cup						See Figure 50.
48	II	0.007	0.016	N	I	S	3219	
49	II	0.008	0.015	N	I	S	3197	
50	II	0.009	0.016	N	I	S	3223	
51	II	0.009	0.017	N	I	S	3211	
52	II	0.007	0.019	N	I	S	3222	

Note: 1. Average weight of sealing cups 5.781 grains.
2. Cup position after insertion and firing. See Figures 23 and 50.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup base and web face.

TABLE XXI.
Test Results of Formulation P28[1]

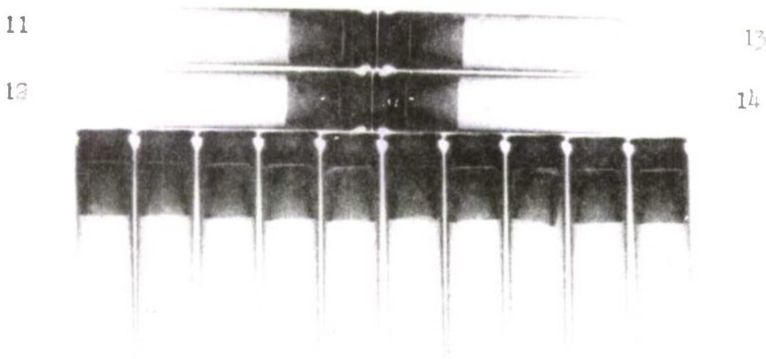
Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
61	II	0.009	0.024	LSp	I	S	3226	
62	II	0.007	0.013	N	N	S	3216	
63	V	Not Fired	Collapsed Cup					See Figure 51.
64	II	0.007		VL	III	VL	3135	Cup partially protruded through induced area; propellant packed tight.
65	II	0.009		VL	III	N	3159	Cup blown out of case.
66	II	0.009	0.014	N	I	M	3213	
67	II	0.009		VL	III	M	3171	Same as 64; collapsed cup.
68	II	0.009	0.019	N	N	S	3203	
69	V	Not Fired	Collapsed Cup					See Figure 51.
70	II	0.005	0.019	MSp	I	M	3252	
71	II	0.014	0.014	L	I	M	3197	
72	II	Not Fired	Collapsed Cup					See Figure 51.
73	II	0.016		VL	III	N	3005	Same as 65.
74	V	Not Fired	Collapsed Cup					See Figure 51.
75	II	Not Fired	Collapsed Cup					See Figure 51.
76	II	0.007	0.013	N	II	M	3189	Case rupture at induced area extending to 9 o'clock clockwise.
77	II	Not Fired	Collapsed Cup					See Figure 51.
78	II	0.008	0.008	N	IIB	L	3198	Face erosion; case rupture from induced area to 3 o'clock, from area into extractor groove to 2 o'clock. Barrel replaced.
79	V	Not Fired	Collapsed Cup					See Figure 51.
80	II	0.010	0.012	N	I	S	3183	
81	II	0.007	0.012	N	I	S	3243	
82	V	Not Fired	Collapsed Cup					See Figure 51.
83	II	Not Fired	Collapsed Cup					See Figure 51.

Note: 1. Average weight of sealing cups 5.088 grains.
2. Cup position after insertion and firing. See Figures 23 and 51.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup base and web face.

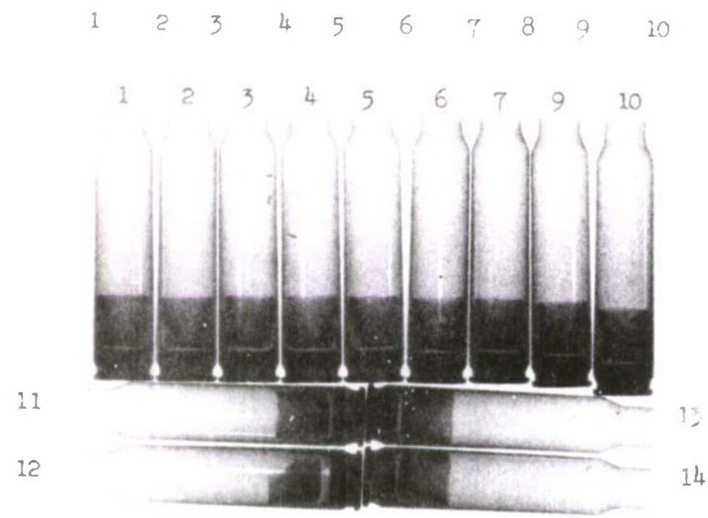
TABLE XXII.
Test Results of Formulation P29[1]

Round	Cup Position After Insertion[2]	FIE Gap (in.) After Insertion[4]	FIE Gap (in.) After Firing[4]	Breech Flash	Erosion Type[3]	Sealing Cup Gas Leak	Velocity (fps)	Remarks
53	II	0.005	0.013	LSp	I	S	3196	
54	II	Not Fired Collapsed Cup						See Figure 52.
55	II	0.006	0.012	MSp	I	S	3207	
56	II	0.001	0.007	N	N	S	3230	
57	II	0.007	0.012	LSp	I	M	3205	
58	II	0.001	0.013	N	I	M	3177	
59	II	0.005	0.013	SSp	I	M	3213	
60	II	0.005	0.013	N	I	S	3216	

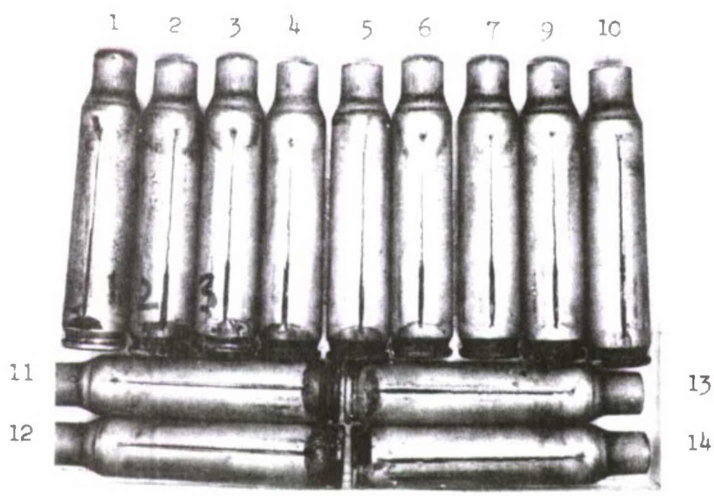
Note: 1. Average weight of sealing cup 5.103 grains.
2. Cup position after insertion and firing. See Figures 23 and 52.
3. Type and location of erosion. See Figure 5.
4. Gap represents distance between cup base and web face.



X-ray view showing cups after insertion

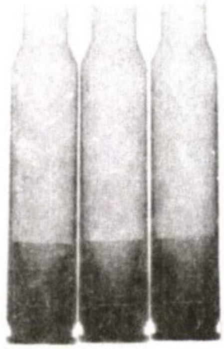


X-ray view showing cups after firing



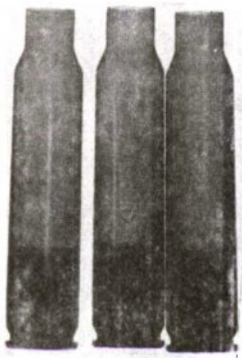
External view of cases after firing

Figure 44. X-Ray and External View of Cases, Formulation P10



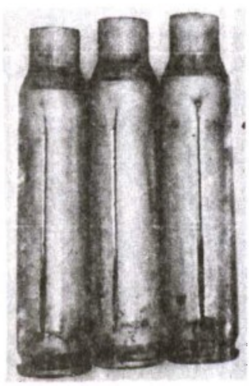
15 16 17

X-ray view showing cups after insertion



15 16 17

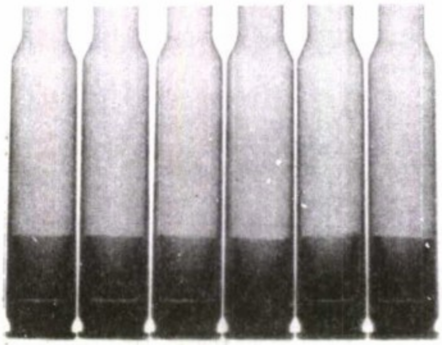
X-ray view showing cups after firing



15 16 17

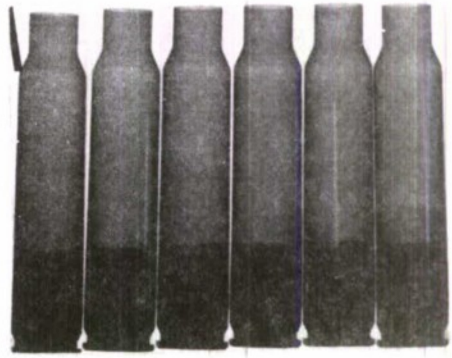
External view of cases after firing

Figure 45. X-Ray and External View of Cases, Formulation P22



18 19 20 21 22 23

X-ray view showing
cups after insertion



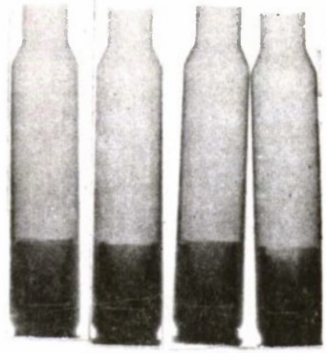
18 19 20 21 22 23

X-ray view showing
cups after firing

18 19 20 21 22 23

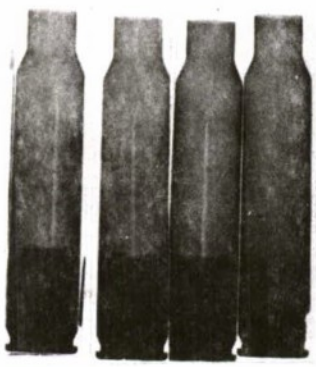
External view of cases
after firing

Figure 46. X-Ray and External View of Cases, Formulation P23



24 25 26 27

X-ray view showing
cups after insertion



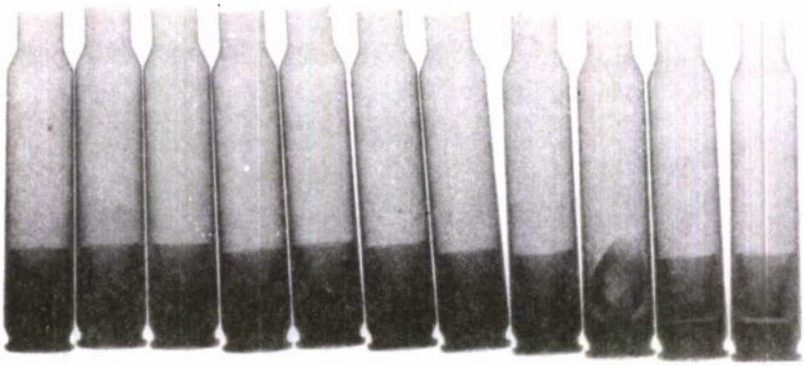
24 25 26 27

X-ray view showing
cups after firing

24 25 26 27

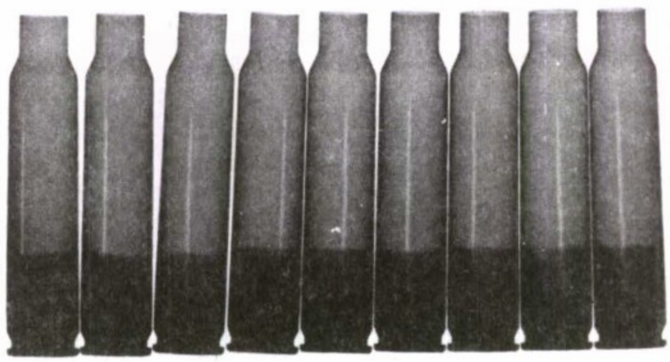
External view of
cases after fire

Figure 47. X-Ray and External View of Cases, Formulation P24



38 37 36 35 34 33 32 31 30 29 28

X-ray view showing cups after insertion



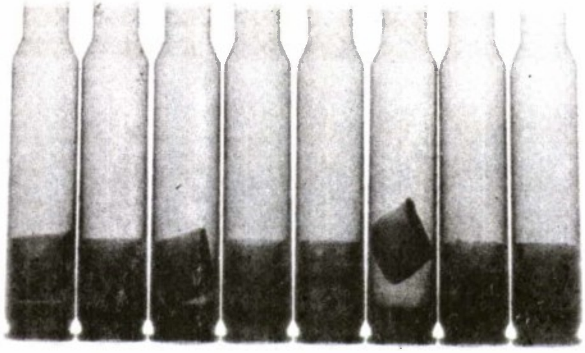
29 31 32 33 34 35 36 37 38

X-ray view showing cups after firing

29 31 32 33 34 35 36 37 38

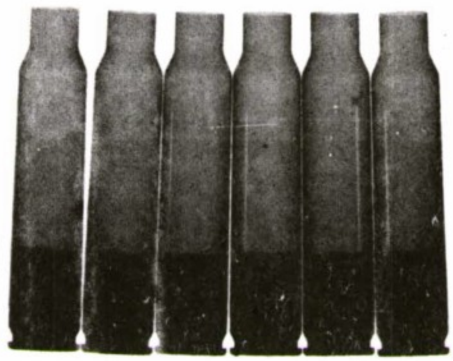
External view of cases after firing

Figure 48. X-Ray and External View of Cases, Formulation P25



46 45 44 43 42 41 40 39

X-ray view showing cups after insertion



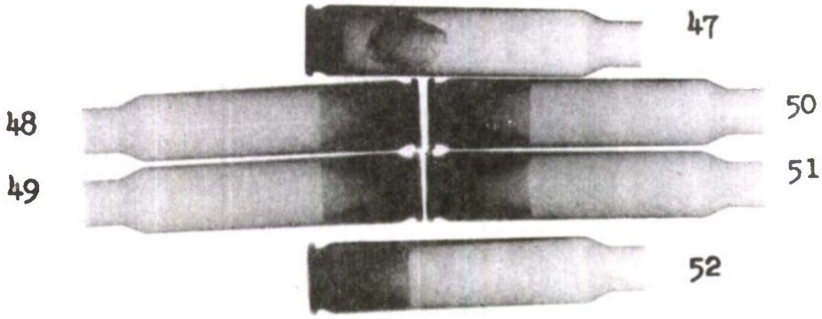
39 40 42 43 45 46

X-ray view showing cups after firing

39 40 42 43 45 46

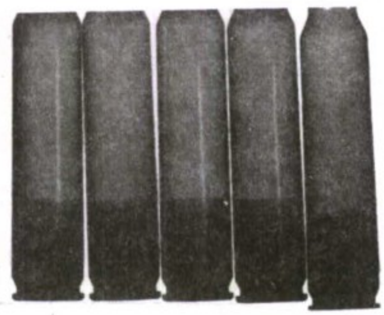
External view of cases after firing

Figure 49. X-Ray and External View of Cases, Formulation P26



X-ray view showing cups after insertion

48 49 50 51 52

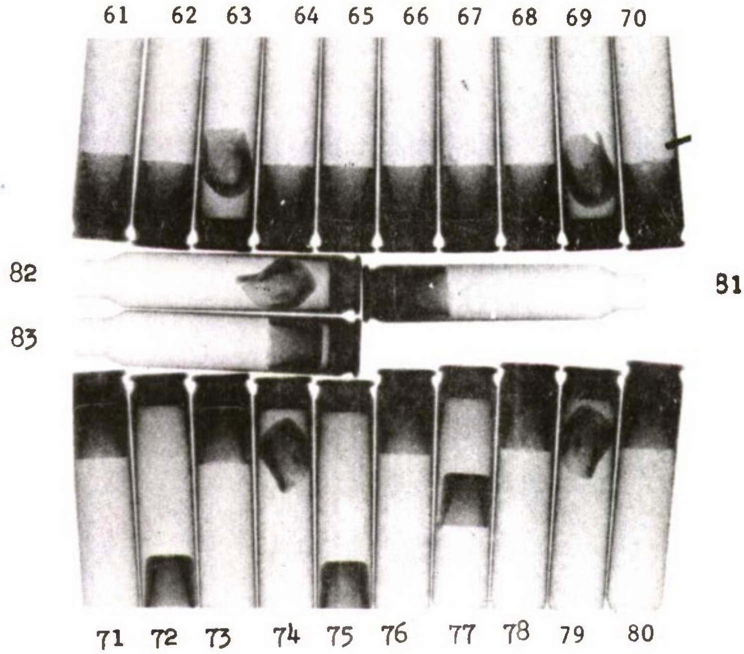


X-ray view showing cups after firing

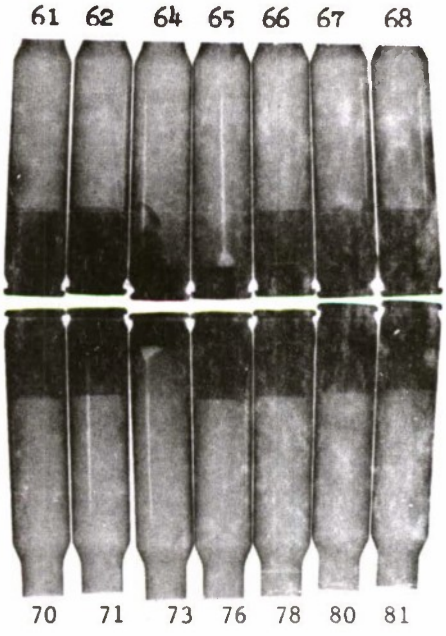
48 49 50 51 52

External view of cases after firing

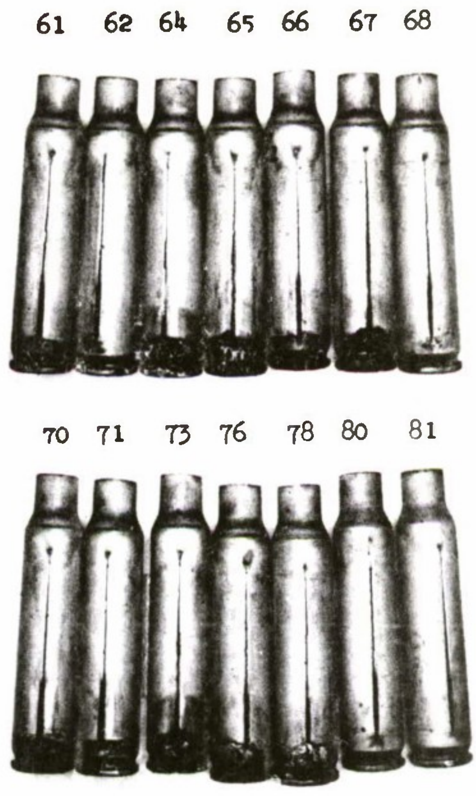
Figure 50. X-Ray and External View of Cases, Formulation P27



X-ray view showing cups after insertion

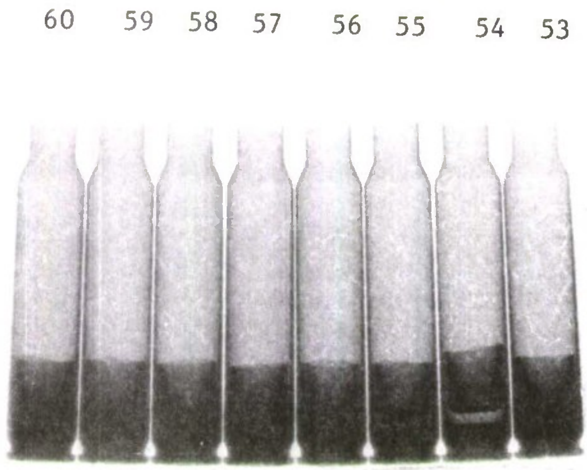


X-ray view showing cups after firing

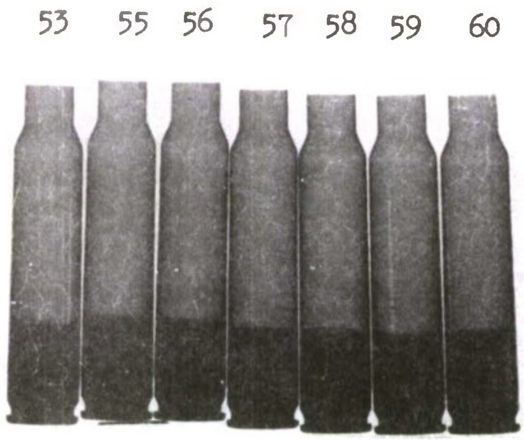


External view of cases after firing

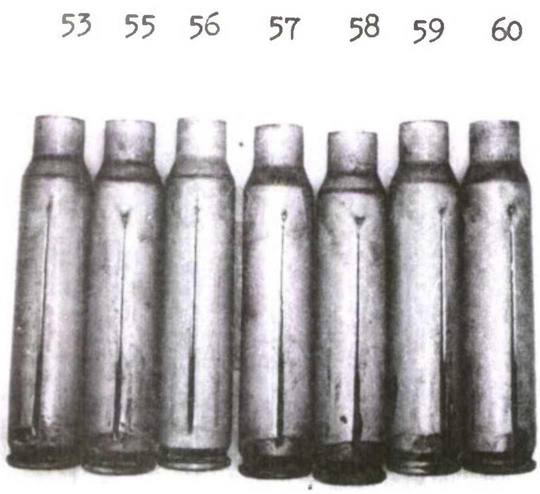
Figure 51. X-Ray and External View of Cases, Formulation P28



X-ray view showing cups after insertion



X-ray view showing cups after firing



External view of cases after firing

Figure 52. X-Ray and External View of Cases, Formulation P29

TABLE XXIII.
Summary of Third Test Firings

Formulation	Identification (As compared to P10)	Remarks and Results
P10	Polysulfide (68 LP32/12 C 5500 Paste/20 Thermax)	Erosion and 31% large breech flashes.
P22	Higher molecular weight polymer (LP31)	Type I erosion, see Figure 23, no breech flash.
P23	10% TP90B Plasticizer	Type I erosion, See Figure 23, no breech flash.
P24	Polymer with greater cross-linking (LP-2), 25% Thermax	Very large breech flash, Types I and IV erosion, see Figure 23 (1 out of 4).
P25	LP-2, 10% Plasticizer	Types I and II erosion, see Figure 23, slight breech spark (1 out of 9).
P26	LP-2, 25% Thermax, 5% Plasticizer	Types I and II erosion, see Figure 23, breech sparks (1 out of 6).
P27	LP-2, 20% Thermax, 5% Plasticizer	No breech flash, Type I erosion, see Figure 23.
P28	LP-2, 29.4% Thermax, 5% Plasticizer	Types I, II and III erosion, see Figure 23, 4 very large breech flashes (out of 14).
P29	Terpolymer of LP-2, LP-205, LP-370, 25% Thermax, 2% Plasticizer	Breech sparks only, Type I erosion, see Figure 23.

TABLE XXIV.
Cost of the Primary Candidate Formulation P27

Ingredient	Content (lbs)	Cost/lb	Extension	Remarks
LP-2	63.8	$1.08	$68.90	Truckload quantity ($1.13 in lesser quantities)
C 5500 Paste	11.2	1.50	16.80	100-199 lb quantity ($1.20 in 400-499 lb quantity)
Thermax	20.0	0.1025	2.05	Truckload quantity ($0.01125 in lesser quantities)
TP-90B	5.0	0.65	3.25	Truckload quantity ($0.68 in lesser quantities)
Cost of 100 lbs			$91.00	
Cost/lb			$ .91	

Production of Polysulfide FIE Sealing Cups

The polysulfide Formulation P10, has been used in preparation of sealing cups in a multiple cavity transfer mold by the Reliable Rubber Products Co., Eddington, Bucks County, PA, 19020. The results indicate the feasibility of such a technique (Appendix B).

Use of Coolant Dihydroxygloxime (DHG) to Provide Reduced Chamber Temperature

Another approach to the use of aluminum cases is to reduce the temperature of combustion of the propellant. Dihydroxygloxime (DHG) has been used effectively as a coolant in solid propellant gas generator compositions and was suggested as an ingredient for propellant ammunition. It was therefore submitted to Frankford Arsenal for test firings. It was substituted for Propellant WC846 at 5, 10, and 15 percent levels and test fired in pressure barrels equipped with Kistler gauges. Results of the test firings are shown in Table XXV and Figure 53. The following observations can be made.

TABLE XXV.
Test Firings with Coolant DHG

Rd No.	Propellant Wt, Grs, WC 846 AL47101	Coolant (DHG) Wt, Grs.	Coolant (DHG) %	Chamber Pressure, (K psi)	Port Pressure, (K psi)	Action Time, (ms)	Velocity (fps)
1	27.1	–	–	55.0	15.0	–	2546
2	27.1	–	–	55.5	15.0	1.577	2568
3	27.1	–	–	55.0	14.8	1.512	2559
Average	–	–	–	55.0	14.9	1.544	2557
4	23.035	4.065	15	66.0	14.5	1.740	2503
5	23.035	4.065	15	62.5	14.3	1.735	2491
6	23.035	4.065	15	58.0	14.5	1.704	2452
Average	–	–	–	62.2	14.4	1.746	2482
7	24.390	2.710	10	60.0	15.0	1.695	2534
8	24.390	2.710	10	55.0	15.0	1.685	2495
9	24.390	2.710	10	51.5	15.0	1.739	2463
10	24.390	2.710	10	55.0	14.8	1.686	2490
Average	–	–	–	56.3	15.0	1.701	2495
11	25.745	1.355	5	54.0	15.5	1.615	2528
12	25.745	1.355	5	51.5	15.0	1.708	2491
13	25.745	1.355	5	55.0	15.2	1.683	2524
Average	–	–	–	53.5	15.2	1.669	2514
14	25.100	1.355	5	47.0	14.0	1.720	2375
15	25.100	1.355	5	48.0	13.5	1.890	2376
16	25.100	1.355	5	49.5	13.8	1.815	2390
17	25.100	1.355	5	51.0	13.6	1.891	2413
Average	–	–	–	48.9			
18	25.100	1.355	5	50.2	13.6	1.806	2397
19	25.100	1.355	5	46.5	13.6	1.843	2363
20	25.100	1.355	5	47.5	13.8	1.960	2372
21	25.100	1.355	5	51.0	14.0	1.718	2410
Average	–	–	–	48.8	13.7	1.830	2387

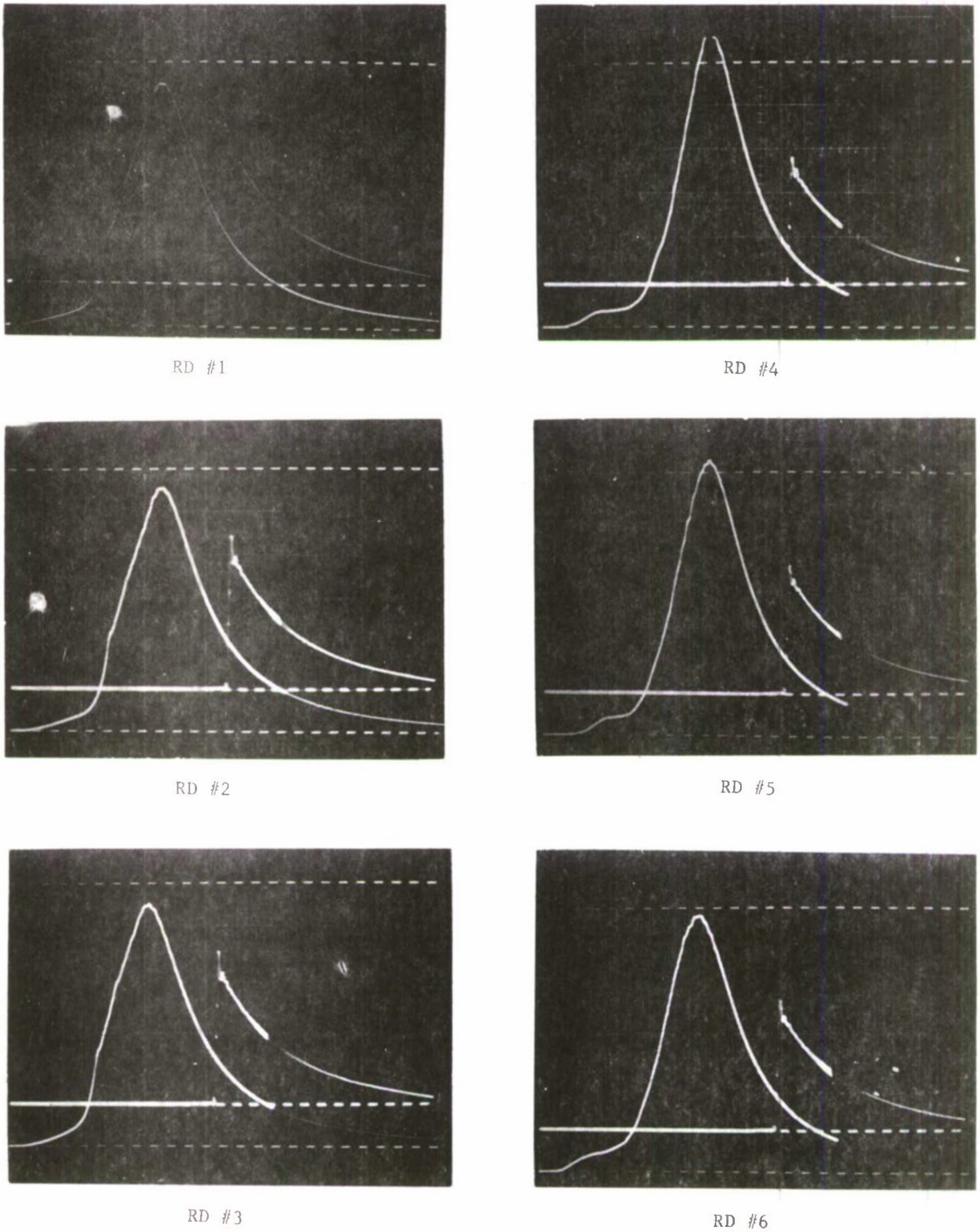
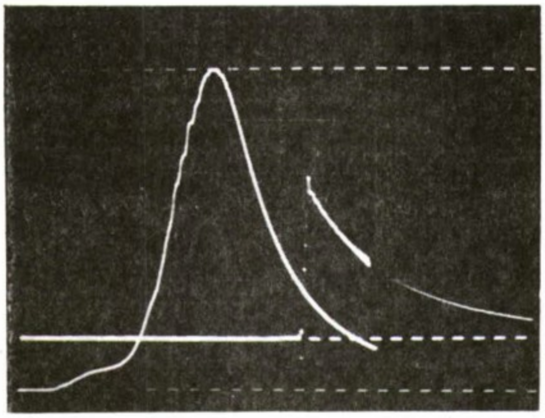


Figure 53. Pressure-Time (P-T) Curves in DHG Coolant Tests



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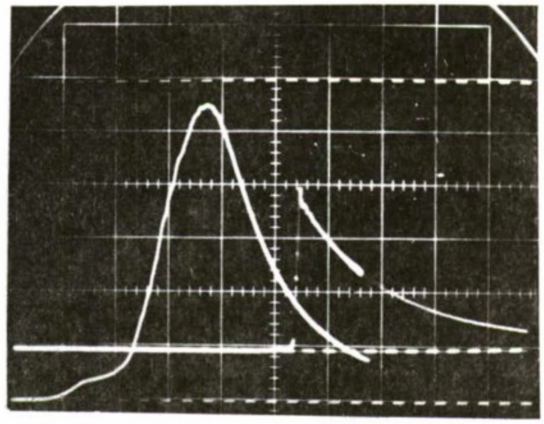

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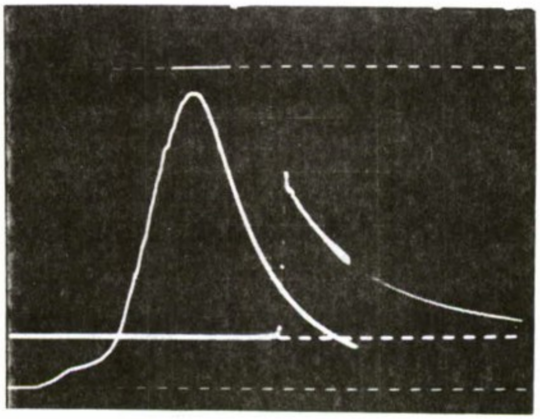

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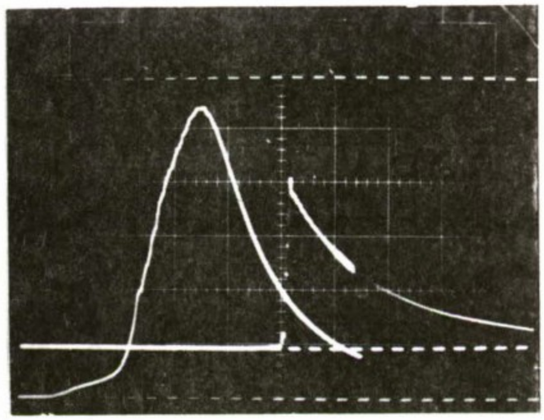

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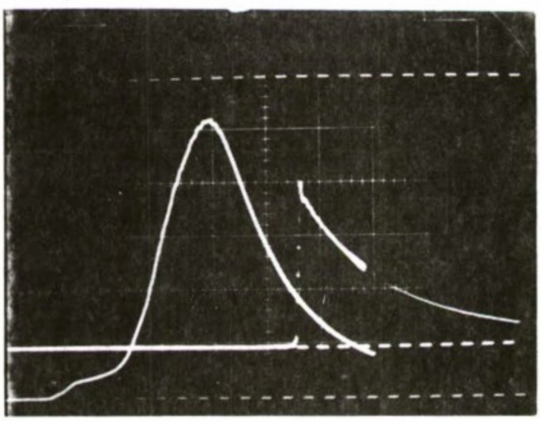

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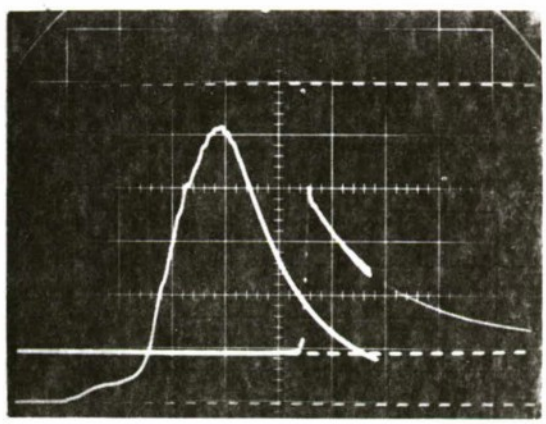
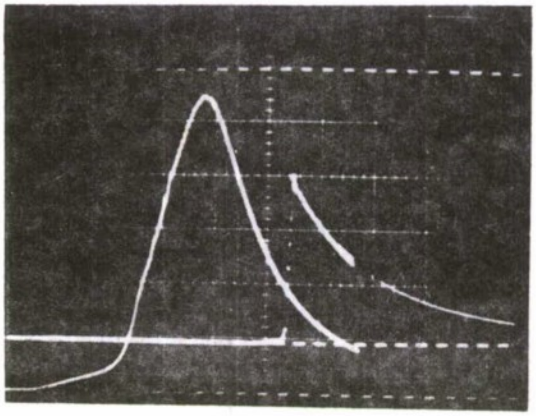


RD #12

Figure 53. Pressure-Time (P-T) Curves in DHG Coolant Tests - Cont'd



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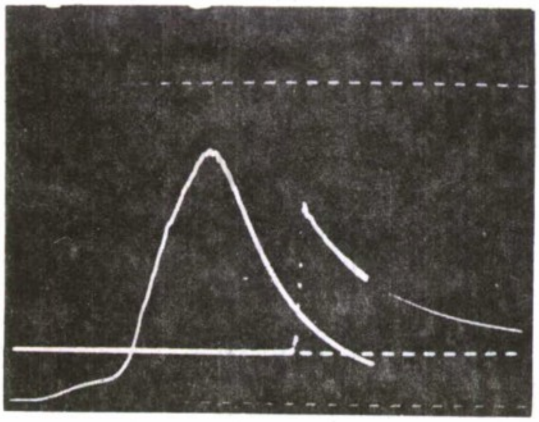

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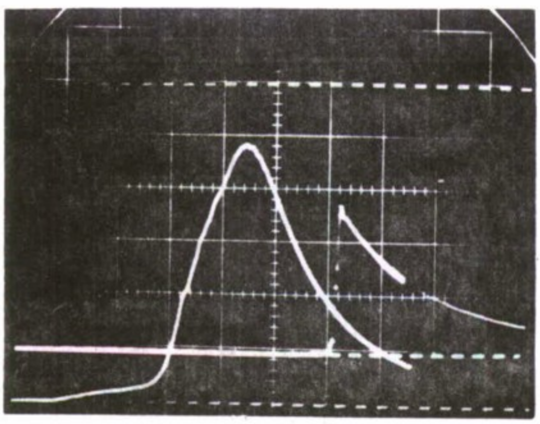

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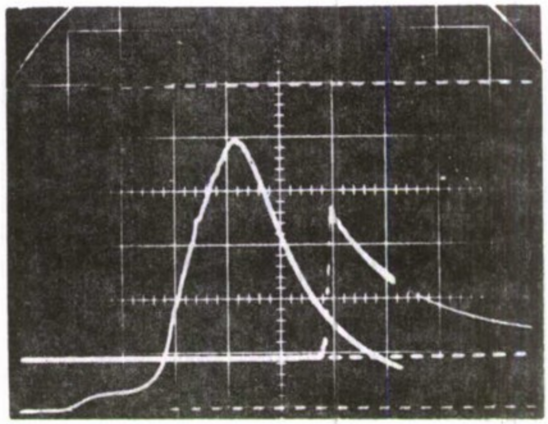

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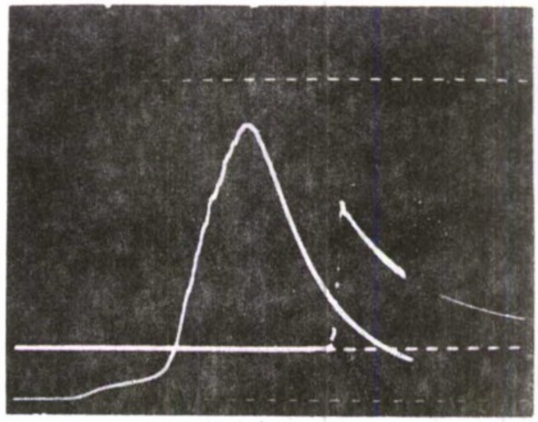

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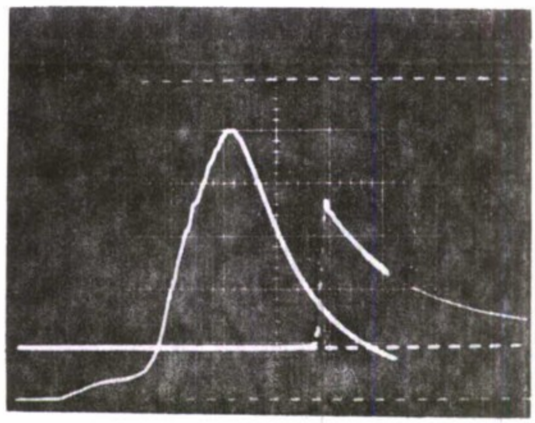

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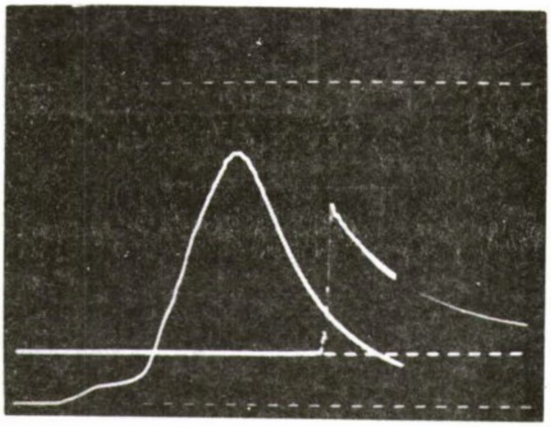
Figure 53. Pressure-Time (P-T) Curves in DHG Coolant Tests - Cont'd



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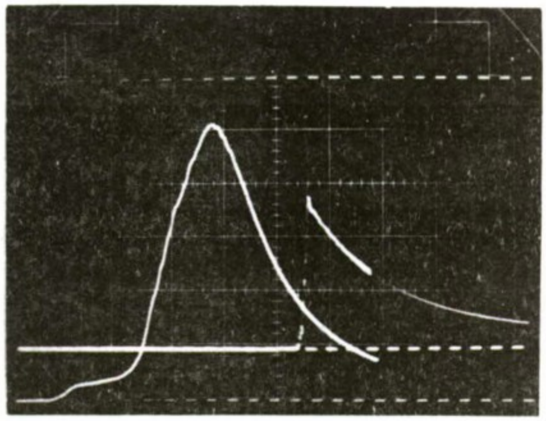

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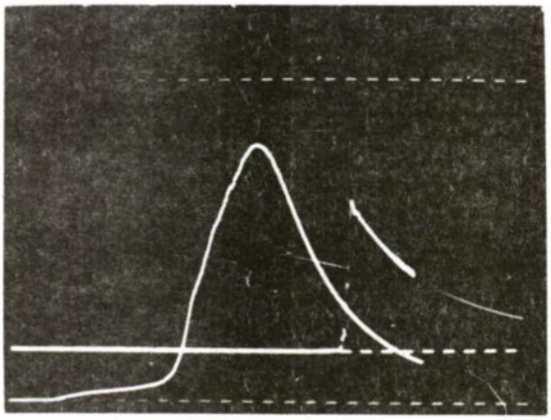

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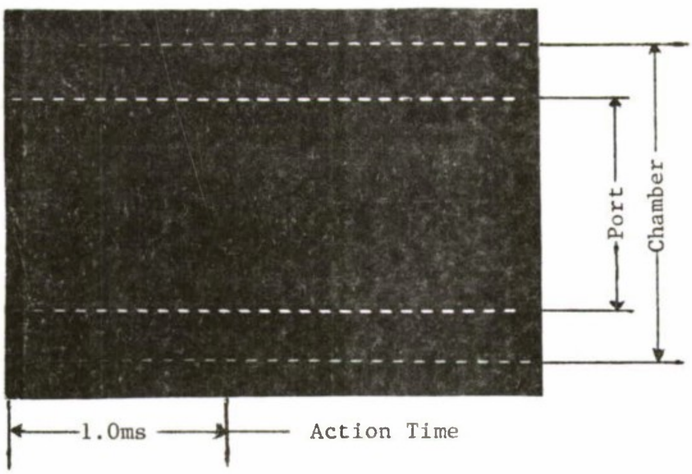

Calibration

Chamber: 60k (10k/line)
Port: 20k (5k/line)
Action Time: Sweep = 0.1 ms/time dot

Figure 53. Pressure-Time (P-T) Curves in DHG Coolant Tests - Cont'd

1. The substitution of DHG, at 15 percent level for WC846 propellant, resulted in a significant increase in chamber pressure by 7,000 psi, decrease in port pressure by 500 psi, decrease in velocity by 75 feet per second, and increase of action time by .200 millisecond.

The following conclusions and recommendations are submitted:

1. Means of increasing the burning rate of DHG should be investigated.

2. The mixing of DHG with the double base propellant during its manufacture should be considered.

3. Theoretical calculations using Aberdeen's "TIGER" computer program should be performed to determine potential reductions in chamber temperature.

4. Consideration should be given to such flame temperature reduction as a means of increasing barrel life.

CONCLUSIONS

1. Test firings of the first series of samples indicated that a Shore "A" hardness of greater than 50 was not feasible since the cups could not be inserted into the cases with the Frankford Arsenal inserting device or were damaged during insertion. Thermax was the most effective filler at the levels tested, and it was not feasible to include effective amounts of Cab-O-Sil because of a loss of processibility. The introduction of ammonium sulfate resulted in an unacceptable loss of physical properties. The use of the TN-L-3011 composition was eliminated because it was found to be impossible to increase cure temperature in order to decrease cure time.

2. The best results in the initial series were obtained with a polysulfide composition labelled P10 (68 LP32/12 C5500 paste/20 Thermax). Another composition, P18 (the same as formulation P10, but with 10 weight-percent Thermax) ranked second in the evaluation. The polyurethanes exhibited excellent tear strength, tensile strength, and elongation, but failed to show test results equivalent to the polysulfides.

3. A second set of five formulations (150 samples), which included Samples P10 and P18, was submitted. Two samples, P19 and P20, contained mixtures of the polysulfide polymers, LP-31, LP-205 and LP-370, in order to provide improved low temperature properties (if necessary). A fifth sample, P21, contained the filler Thermax at a level intermediate between that of P10 and P18. Difficulty in inserting these samples into the aluminum cases was encountered because of a tendency of the cups to collapse.

4. A third set of samples was formulated to correct the tendency to collapse. Variables included were increased polymer molecular weight (LP-31), increased polymer functionality (LP-2) (to increase crosslinking), carbon black content, and the addition of a plasticizer (TP-90B). Of these, the polysulfide formulation P27 (63.8 LP-2/11.2 C5500 paste/20.0 Thermax/ 5.0 TP-90B) showed the best results in test firings. This formulation, which costs \$.90/lb (at current prices) was recommended for further investigation. Physical properties were: density equals 1.33 g/cm^3, tensile stress equals 137 psi, elongation equals 312 percent, tear strength equals 42 pounds per linear inch (pli). The cups used in this test were 5/16 inch in length (vs 13/32 inch), and the feasibility of using this cup size was demonstrated.

5. The coolant dihydroxyglyoxime (DHG) was found to significantly increase chamber pressure when substituted at 15% levels for propellant WC846.

RECOMMENDATIONS

It is recommended that:

1. The Formulation P27 be subjected to large-scale testing, including testing at various temperatures.

2. Formulations containing calcium peroxide (in place of lead peroxide) and Sterling Black R (in place of Thermax) be investigated. The former may still further reduce any tendency toward cup collapse; the latter should increase strength (at a lower level than Thermax) without increasing stiffness.

3. All FIE cup compositions be examined by the Taliani Test to determine (through measurement of gas evolution at elevated temperature) the long-term compatibility between the composition and the propellant.

4. The addition of the monopropellant, dihydroxyglyoxime (DHG), which functions as a coolant in solid rocket propellants, be further investigated as a means for reducing the temperatures generated by the propellant in aluminum cartridges.

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1. Reed E. Donnard and Thomas J. Hennessy, "Aluminum Cartridge Case Feasibility Study Using the M16A1 Rifle with the 5.56 mm Ball Ammunition as the Test Vehicle," Frankford Arsenal Report No. R-2065, November 1972.

2. W. H. Squire and R. E. Donnard, "An Analysis of 5.56 mm Aluminum Cartridge Case Burn-Through Phenomenon," Frankford Arsenal, AD 750379, 1972.

3. Samuel J. Marziano and Dr. Calvin Vriesen, "Prevention of 5.56 mm Aluminum Cartridge Case Burn-Through," Frankford Arsenal Report No. FA-TN-75002, January 1975.

4. "Proposal for Evaluation of Materials to Provide an Insulation Sleeve for 6.00 mm Aluminum Cartridge Cases," Thiokol Proposal No. EP301-73, 19 January 1973.

APPENDIX A

Typical Barrel Erosion from First Test Firing

The figure shown below represents a typical erosion of a test barrel due to ineffective flexible internal element (FIE) design.

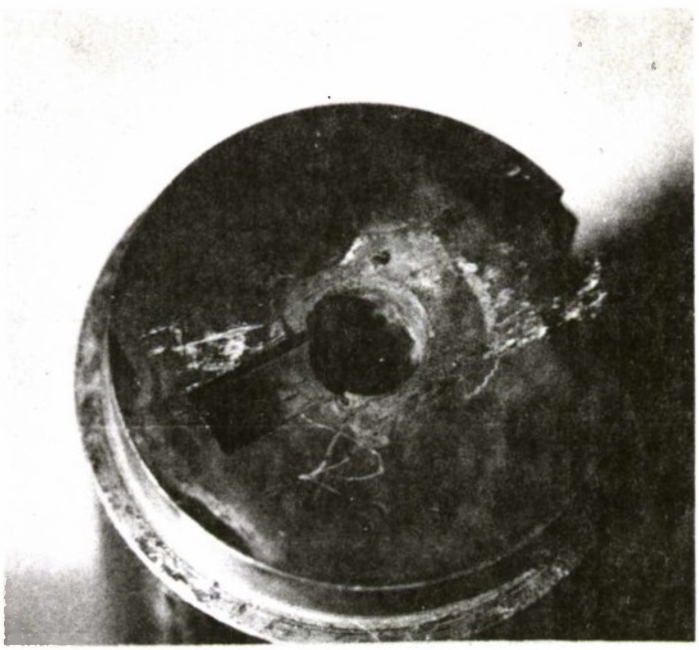

Figure A-1. Typical View of Test Barrel Erosion

APPENDIX B

Letter of Confirmation for the Multiple Cavity Producing of Formulation P10

May 14, 1974

Dr. Vriesen
c/o Thiokol Chemical Corporation
Elkton, Maryland 21921

Subject: Shipping Document 74-0335 dated 5/2/74

Reference: Thiokol Formulation P-10

Dear Dr. Vriesen:

We are enclosing 40 pieces of Frankford Arsenal Part No. J7300-8-20-73 as produced from your formula P-10 from the existing multiple cavity compression transfer mold. These are FIE cups for the 6 MM size.

As explained by our laboratory manager, Mr. Art Enders, he made various attempts using the single cavity experimental mold and finally found that he was able to get a good configuration, smooth surface, and what appears to be a satisfactory cure by not degassing and by press curing in a preheated mold for 15 minutes at 200° F.

As a result of your discussion, he proceeded with a trial from the production mold as follows:

(1) The ratio of 88 grams Part A, and 12 grams Part B was established and the components were thoroughly blended at room temperature.

(2) The blend was allowed to sit for 10 minutes before using.

(3) Mold cavities were lubricated with a light film of ASTM No. 1 oil.

(4) Compression transfer of the material was effected and the closed mold was subjected to a 15 minute cure at 200° F.

We are enclosing what we feel to be the 40 best parts out of the 69 cavity mold, and hope that you will find at least the 30 that you require to be satisfactory for your use.

In the event that you are unable to use the parts, kindly return them and there will be no charge.

If the parts are satisfactory and you feel that you would want us to proceed with a program using other formulae, we will be happy to submit a quotation covering the above item with others as a lot charge, or work on an item to item basis.

Thank you for this opportunity to be of service.

Very truly yours,

RELIABLE RUBBER PRODUCTS COMPANY

Herbert E. Haefner
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